Heat-Treatment—Electric Furnace *for* Duralumin Sheet

By Robert J. Anderson, MET.E., D.Sc.*

WHILE several different types of furnaces have been used for the heat-treatment of aluminium-alloy manufactures, the electric-resistance furnace is favoured by most metallurgists. In the heat-treatment of duralumin (and other strong alloy) sheet the material is first heated to about 500° C., soaked for a sufficient period of time, and then quenched in water or oil. It is then aged at room temperature or treated by an accelerated ageing process (at moderately elevated temperature), in order to develop strength and hardness.

Detailed discussion of the relative merits of electric furnaces, fuel-fired furnaces, and salt baths (usually fired by oil or gas) as heat appliances in the aluminium-alloy field need not be given here. In the writer's opinion, electric furnaces of the metallic-resister (Nichrome) type are more efficient, more easily controlled as to temperature, may be more uniformly heated, and are more easily operated than fuel-fired equipment.

In the present article, brief description is given of a new-type electric furnace designed especially for heating duralumin-type sheet prior to quenching. The furnace, as designed, or with certain modifications, is also well adapted for the annealing of aluminium and aluminium-alloy sheet and other manufactures, and for the heat-treatment of castings. This furnace was designed by the Gas Equipment Engineering Corp., Philadelphia, Pa., and built for the Fairmont Aluminium Co., Fairmont, West Va. Another furnace of similar design had previously been built by the first-mentioned company for the heat-treatment of steel tubing and other materials for aircraft.

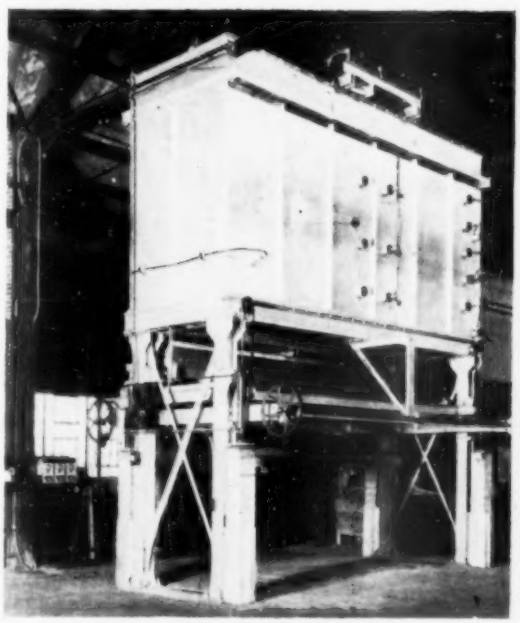


Fig. 1. General view of Electric Heat Treating Furnace. Door open.

An important feature of the present furnace is the position of the heating chamber with relation to the quenching tank. As will be noted from the accompanying illustrations, the heating chamber is directly above the tank. Work to be quenched may be transferred rapidly from the furnace to the quenching bath without appreciable loss of heat.

Design and Construction.

In the quenching heat-treatment of aluminium-alloy manufactures there are four main factors that determine the final properties of the materials, viz., (1) accuracy of temperature control, (2) uniformity of temperature throughout the charge, (3) temperature of quenching, and (4) uniformity of quenching. The furnace described here was designed with a view to controlling these factors as closely as might be practical.

Accuracy of temperature control is possible only with modern automatic electric mechanism; numerous satisfactory makes are available. Uniformity of temperature within a furnace chamber depends upon the distribution of the heating elements (in the case of an electric furnace), insulation against heat losses, and adequate circulation of the atmosphere. The quenching temperature is governed not only by the temperature to which work is heated, but also by the lapse of time between removal from the furnace and introduction into the quenching bath. Uniformity of quenching is dependent on the method of introducing the work into the bath, spacing between separate pieces, and speed of immersion. The design adopted for the furnace dealt with here appeared to include all the features required for satisfactory heat-treating results. Under practical operating conditions the performance of this furnace is excellent.

Fig. 1 shows a general view of the furnace as constructed, and Fig. 2 shows a view from the opposite end. In Fig. 1 the bottom door is open and has been moved to one side, while in Fig. 2 it is closed. Assembly drawing and details of the various parts that go into the construction of the furnace cannot be shown here.

Inside dimensions of the heating chamber are 4 ft. 2 in. wide by 17 ft. 8 in. long by 8 ft. high (this latter being measured from inside the bottom door to the base of the roof arch, this arch being 7½ in. high). Maximum overall height of the furnace from the floor to the top of the charge-handling mechanism is about 25 ft. 6 in. Part of the charge-handling mechanism is shown at the top of the furnace (*cf.* Figs. 1 and 2). The width of the bottom door is 2 ft. 9 in. Sheets measuring up to 7 ft. wide by 16 ft. long may be heat-treated in this furnace. The heating chamber is elevated 11 ft. 6 in. above the floor, being carried on four 8-in. **H** beams as supporting columns. These columns are anchored securely to concrete piers by means of hook bolts. The side and end walls of the furnace are encased in $\frac{3}{16}$ in. steel plate, the roof in $\frac{1}{8}$-in. plate, and the bottom door in $\frac{1}{4}$-in. plate. All structural work is of steel, designed with a liberal factor of safety. The plate sections are welded together before erection. The entire structure is made very rigid by reinforcement with shapes and buckstays.

Side and end walls are 12 in. thick, exclusive of steel plates. The inner wall, in which the insulating refractory supports for the heating elements are set, consists of a course of Armstrong calcined insulating brick 4½ in. thick. This is backed up by a course of Armstrong Nonpareil insulating brick 4½ in. thick, and this, in turn, by a 3-in.

*Consulting Metallurgical Engineer, Cleveland, Ohio, U.S.A.

thick layer of Sil-O-Cel coarse grade insulating powder. This latter is in contact with the steel housing plates. The inner wall of the top arch consists of a course of Armstrong calcined insulating brick 4½ in. thick, and this is backed up by a layer of Sil-O-Cel insulating powder—the thickness of this layer varying from 7½ in. at the centre of the arch

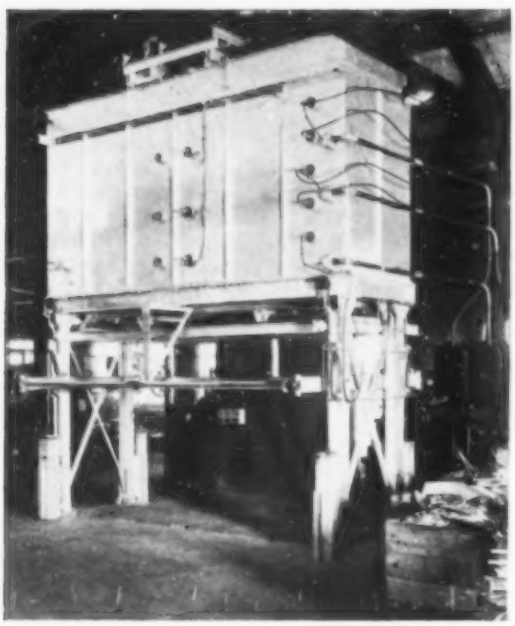


Fig. 2. General View of Furnace with door closed.

to 14¾ in. at the base. The inner wall of the bottom (formed by the door) is made of a 4½-in. thick layer of Armstrong calcined insulating brick, backed up by three courses of Nonpareil insulating brick. Total thickness of the door is 10 in., exclusive of steel plates.

The bottom door is in the form of a car which may be moved horizontally out to one side from under the furnace opening, and also vertically for a limited distance. Wheels on the sides act as guides for the vertical movement, and the door runs on wheels arranged underneath in moving to one side. The door movements are controlled by air-cylinder valves. Cast-iron counterweights are used for balancing the weight of the door. A sand trap acts as a seal; this extends around all four sides of the car door. When the door is raised up to close the chamber opening an angle iron is forced into the sand, thus making a seal. The door rests on a platform (measuring about 10 ft. wide by 17 ft. long) when lowered from the opening. Two rails are mounted on this platform; the car door travels on these rails when moved horizontally. Fig. 3 is a close-up view of one end of the structural supporting work, showing the door counterweights, air-cylinder valves, part of the door (upper left hand), suspension frame for holding the sheets (lower centre), and quenching tank.

The quenching tank is 3 ft. 6 in. wide by 17 ft. long by 8 ft. deep. This tank is sunk in the floor beneath the furnace structure. It is built of concrete and waterproofed. Water ingress and egress lines are provided, as well as a drain.

Sheets are hung on a suspension frame which is attached to a charge support beam. This beam is raised and lowered by means of two cables which are wound up on drums by means of motor drive. The motor, together with worm-gear reducer, drums, couplings, shafts, etc., is mounted on top of the furnace. The suspension frame (*vide* Fig. 3) is 12 ft. 6 in. long by 2 ft. 6 in. wide; it is provided with four slots, in which four sheets or four sets of sheets may be suspended by wedges. A carriage, shown extending out from the supporting columns on both sides in Figs. 1 and 2, is used to hold the suspension frame when loading or unloading sheets. This carriage is about 7 ft. 6 in. from the floor. It may be moved by a sprocket chain to either side of the furnace. The suspension frame, beam, and other parts of the charge-handling equipment that are exposed to the furnace heat are made of heat-resisting alloys. If aluminium-alloy castings or other parts are to be heat-treated, suitable baskets may be used for loading—such baskets being attached to the suspension frame.

The heating elements are made of 0·055 in. by ¾-in. Nichrome resistance ribbon, the total active heating length being 1376 ft. The ribbon is wound back upon itself every 7⅜ in., and the resulting parallel sections are 1½ in. apart. Self inductance is held at a minimum with this form of winding. The ribbons are hung on alundum refractory shapes that extend 2 in. from the inside walls, these shapes being set in the calcined insulating brick. There are two rows of ribbons extending around the walls in each of the top and centre heating zones. The lower heating zone has two rows of ribbons in the bottom door, and one row along the inside walls below the centre zone.

The furnace is rated at 135 kw., and is operated on a 60-cycle three-phase line at 220 volts.

In order to provide circulation of the furnace atmosphere, and thereby increase the uniformity of temperature throughout the chamber, three fans are mounted in the arched roof. Drive is by small motors. These fans force the air downwards. The shaft openings are sealed with flanges to prevent loss of heat.

Fig. 4 shows the three temperature controllers (at the right) and a recorder (at the left). Two of the three relay boards are shown at the right of Fig. 2. A thermo-couple is provided in each of the three heating zones, and is connected to individual controllers. The controllers used in the present installation were supplied by the Wilson-Maeulen Co., Inc., New York, N.Y. Temperature readings

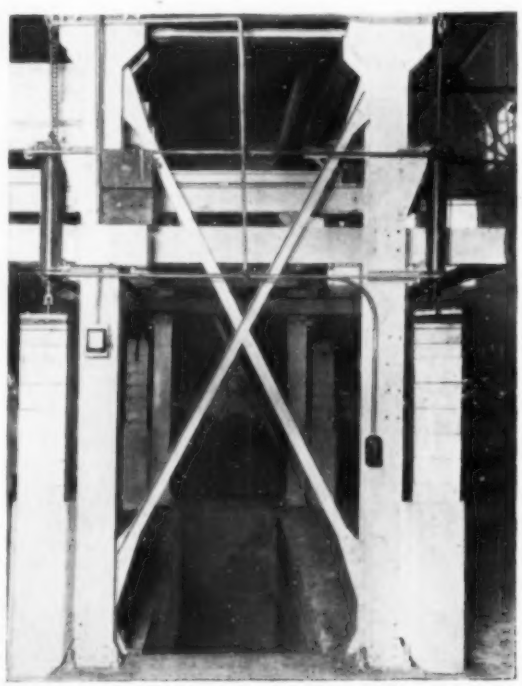


Fig. 3. View showing Supporting Columns and Under Work of Furnace.

in the three zones are recorded continuously by the four-point Tapalog recorder (Wilson-Maeulen). The three thermo-couples may be seen in the centre of the side wall shown in Figs. 1 and 2.

Operation of the Furnace.

In the production operation of this furnace the procedure is about as follows :—Work to be heat-treated is moved up to the side of the furnace on trucks. With the chamber at the proper temperature the bottom door is lowered and moved to one side. Rapid operation calls for the use of two suspension frames. It will be assumed that an empty frame has been in the furnace during the heating. This frame is lowered after the door has been moved away, and is allowed to rest on the carriage. The cables are disconnected from the frame by removing clevis pins. The charge has been previously loaded on the second suspension frame resting on the carriage. This is then moved over to the proper position under the opening, the cables attached, and the load raised into the chamber. An automatic stop on the hoist stops the frame when it reaches the desired height. The car bottom is next moved back under the opening and raised so as to seal the furnace.

Power is shut off before the furnace is opened, and thrown on after the load has been charged and the bottom closed. The controllers may then be reset if required. The fans are set in motion when the power is thrown on and stopped when it is shut off.

When the charge attains the required temperature and has been held for a sufficient length of time the power is thrown off, the car bottom lowered and moved to one side, and the charge is lowered rapidly into the quenching bath. An automatic stop on the hoist regulates the depth of drop into the tank. The charge is then raised from the tank to a height slightly above the carriage, the carriage is moved to a position directly under the suspension frame beam, and the beam is lowered on to the carriage. Cables are disconnected, the quenched charge moved to one side, the new charge is put in, and the operation repeated as before. The quenched charge is unloaded, and a new charge prepared while the last charge is being heated. When using two suspension frames, the speed of quenching and charging is so rapid that it will not ordinarily be necessary to close the bottom door to avoid heat loss. In the preferred operation two suspension frames are used, and the loads are charged from one side of the furnace and discharged from the other side.

The frames and load should be dry before being charged. Moisture in the furnace atmosphere is to be avoided in order to prevent staining of the sheets being treated.

In annealing aluminium or aluminium-alloy sheets the charges are loaded as described above, and after heating for the required period of time are lowered from the furnace, the suspension frame resting on the carriage so that the cables may be disconnected (as described above).

It has been found that aluminium sheets when annealed in small lots in this furnace have better mechanical properties than when annealed by the batch method in car- or pan-type furnaces. This follows naturally because of the shorter time period of heating and smaller grain size that results.

Cost of Operation.

This furnace has not been in operation for a sufficient length of time to permit the accumulation of detailed costs of operation. However, some figures have been obtained that will serve to give an idea of the probable cost.

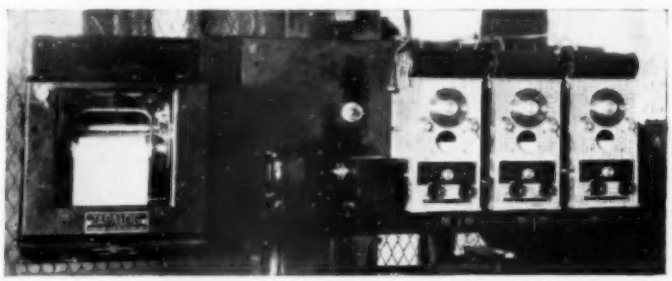


Fig. 4. Temperature Controllers and Recorder for this Electric Furnace.

The furnace erected and ready to run cost about $10,000. Assuming a probable life of 20 years before it becomes obsolete, the annual charge off for obsolescence would be $500. It is estimated that the lining and heating elements will last at least five years before renewal is required. Complete set of heating elements costs $900, and material for lining costs about $325. Figuring labour at 50 cents per hour, and power at 1 cent per kwh. (including the demand charge), and the capacity of the furnace at 500 lb. per hour (300 days per year, 12 hours per day), the following cost set up arises :—

Item.	Cent per Pound.
Obsolescence	0·028
Interest on first cost	0·033
Linings	0·004
Heating elements	0·010
General maintenance, including major repairs to linings and heating elements	0·015 (?)
Labour	0·100
Power	0·140
Total	0·330

The chief items of expense are power and labour. Cost of around 0·3 cent per pound for operating this furnace compares favourably with costs for other electric furnaces of which the writer has knowledge. The power cost may be considerably higher, depending upon the method of operating the furnace and upon the cost of purchased electric energy.

Chrome Plating and Anodic Oxidation.

MUCH attention has been directed to the risk of injury to workers employed in the processes of electrolytic chrome plating and anodic oxidation which have recently been introduced. The effect of these processes on the workers' health has been the subject of careful investigation by H.M. Medical Inspectors of Factories, and a summary of the results of this investigation has been prepared. More than 200 persons engaged in these processes were medically examined, and the examinations showed that in the case of more than half of these workers the mucous membrane of the nose had been affected by the spray generated, and in a number of cases ulceration had led to complete perforation of the septum. The skin of other parts of the body —usually the hands or feet—showed evidence of dermatitis or ulceration, due to contact with the solutions used, in more than 40% of the cases examined. It is important, therefore, to ensure that effective measures are taken to minimise the risk of injury, and, where injury has arisen, to provide prompt and adequate treatment.

It is important to note that ulceration of the nasal mucous membrane was seen after only two weeks' employment, and the length of employment of those who showed perforation of the nasal septum varied from six months to four years. These effects are caused by the spray carried into the atmosphere, and the risk can only be eliminated by efficient exhaust ventilation.

In these circumstances it is not surprising that the Secretary of State has certified the processes to be dangerous, and he proposes, as has been done in similar cases, to supplement the general law by means of regulations. The chief requirements are exhaust ventilation, provision of protective clothing, washing facilities, periodic inspections of the hands and forearms, and periodic medical examination by the Certifying Surgeon or by a doctor appointed for the purpose, who is empowered to suspend workers from employment in processes involving contact with the liquids.

A summary of the results of the investigation together with a draft of the proposed regulations can be obtained from the Home Office, Whitehall, S.W. 1.

Strip Rolling Mills

By W. W. Robertson, B.Sc.

GENERALLY, strip metal may be regarded as metal which can be coiled in long lengths, and is distinct from sheet metal, which is rolled flat and in short lengths. The use of strip metal is primarily for press work and, as the scope of press work is developing very rapidly, strip rolling is increasing in importance. The application of the principles of mill design varies considerably according to whether ferrous or non-ferrous metals are to be rolled, and also whether the hot- or cold-rolling method is to be adopted. The types of rolling mills used may be classified as the two-high, with its development the double-duo mill, three-high, four-high, and cluster, of which the commonest type in general practice is the two-high mill.

It is necessary from the standpoint of economy to reduce the metal at each pass the maximum amount possible. For this purpose small-diameter rolls bite the metal better than those of large diameter, and, in addition, consume less power. The factors determining the size of roll to be used are two: (1) strength of the roll; (2) the difficulty of entering thick metal between small rolls when a heavy pinch is taken—the two considerations have to be balanced when deciding the diameter of roll to be used.

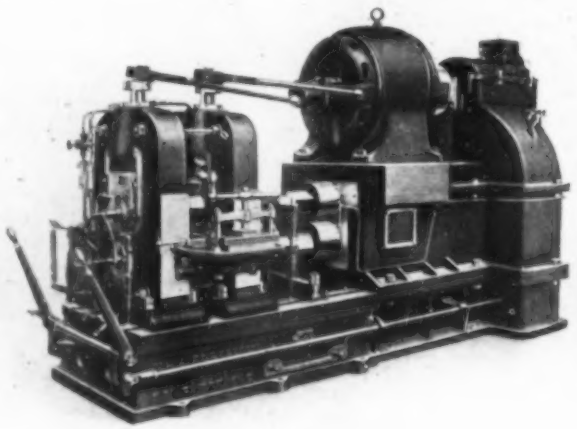


Fig. 1.—10 in. × 10 in. Mill fitted with Flood Lubrication Bearings.

In order that the mill can accommodate various thicknesses of metal the top roll must be adjustable, and a flexible coupling is necessary between the pinion and roll housings. The couplings are usually of the muff type. The pinions are double helical, and are now invariably machine-cut arranged to run in an oil-bath. The housing, particularly for cold mills, is generally a heavy steel casting, because of the heavy strains to which it is subjected. In the case of hot mills, the same degree of rigidity is not so essential, and cast-iron housings of lighter construction are usually employed for this work. The bottom roll bearing is carried direct in the housing, while the bearing for the top roll is usually carried in a steel chock, which can be moved up or down.

The roll bearings are so heavily loaded that experiments have shown as much as 60% of the power consumed in a mill is used in overcoming this friction at the roll necks. The maximum speed at which cold rolling could be accomplished, until a few years ago, was at 80 ft. per min. Greater speed than this, with reasonably heavy reductions, heated the bearings to such an extent that inaccuracies in thickness of rolled strip resulted, and the power consumed was excessive.

There have been many attempts to increase the speed of rolling by improvements in bearing design. with varying degrees of success. Roller bearings have been fitted extensively with good results on hot mills and light-type cold mills, where the loads are relatively small, but not with entire success on heavy cold mills. This is due to the reduction in the neck diameter necessary to accommodate the roller bearing. For instance, on a mill having 10-in. diameter rolls, a bearing with an outside diameter of 9¾ in. is about the maximum that can be used, which would give a neck diameter of about 5 in. against the standard of 7½ in. The reduction in neck diameter is so great that the roll is weak. In addition, the load is so heavy on the bearing that the life is limited, involving expenses in renewals. However, the saving in power is a very definite economy.

Another type of bearing recently developed by Messrs. W. H. A. Robertson and Co., Ltd., is a new patent "flood" lubrication type, in which oil is circulated through the bearing itself under low pressure. In this method the oil forms a continuous oil film between the roll neck and bearing. This type of bearing has not yet been applied to hot mills, as the older type of bearing is satisfactory as loads are not heavy, but for cold mills its use has resulted in speeds four times the previous speed, and very heavy pinches can be taken with the bearings perfectly cool. Up to the present the maximum speed attempted with these bearings is 300 ft. per min.; but as the speed of rolling increases the oil film becomes more robust, and it is likely that cold rolling speeds will increase further during the next few years. With this type of bearing and a 10-in. diameter roll the neck is usually 7½ in. diameter, and, consequently, is obviously stronger than the 5-in. diameter neck when a roller bearing is installed. The illustration Fig. 1 shows a modern 10 in. × 10 in. mill fitted with these bearings.

A further type, which is really a development of the two-high mill, is the double-duo mill, used entirely for hot rolling. This consists of two pairs of rolls, the strip being brought through the top pair and returned through the bottom pair.

The width of strip which can be produced on a two-high mill is limited by the strength of the rolls. As the gauge is reduced the spring on the rolls makes it impossible to produce accurate wide strip. This has led to the development of the three-high, four-high, and cluster mills, which are gradually being introduced at the present time. In each case the principle is to maintain the size of roll which will give heavy reductions with maximum efficiency, and support it by other rolls. The small-diameter working roll is thus backed up by idle large rolls, which gives the mill that rigidity necessary for producing wide widths of accurate gauge. This development has enabled the use of a smaller diameter of working roll than had hitherto been possible. An additional advantage of these mills is that roller bearings can be used on the backing-up rolls, the difficulty of the small neck being overcome by increasing the diameter of the idle roll, which allows the neck to be increased.

The development of these backed-up-type mills has placed the brass and steel rolling mills in a very unsettled condition respecting future developments. Details with regard to actual practice are as yet somewhat vague, but it is interesting to summarise the advantages and disadvantages claimed for these types over the two-high mill. The advantages are:—

(1) Large reductions can be taken before the metal

requires annealing, this being due to the small diameter of the roll used. It is also considered that less power is required for any given reduction.

(2) The number of anneals necessary are lessened because the metal may be reduced further before annealing. This is a very important advantage.

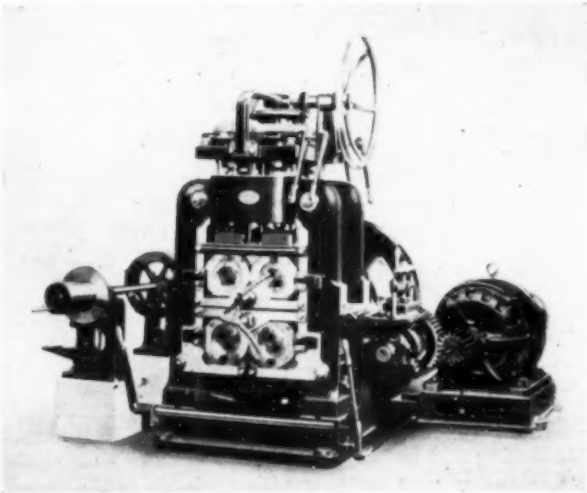


Fig. 2.—Cluster Mill—for Thin-gauge Metal, 5 in. dia. Work Rolls, 10 in. dia. Backing Rolls.

(3) A wider width of accurate gauge strip can be cold rolled. Previously, in rolling wide strip, it had been impossible to obtain accuracy in the thinner gauges except by pack rolling, due to the weakness of the large face rolls used and also the large-diameter rolls necessary to have a reasonable rigidity. The introduction of backed-up mills has increased the width of narrow-gauge strip produced from 20 in. in the case of steel and 28 in. in brass to 40 in.

Against these very definite advantages are :—

(1) The difficulty in keeping the rolls in line.

(2) The smaller size mills produce a bad finish and inaccuracy of gauge owing to the roll heating up, which causes the metal to vary in gauge from end to end of the coil.

(3) Camber is necessary on the working rolls, in spite of the additional strength of the backing rolls, which increases the difficulty in maintaining alignment.

(4) Increased cost in upkeep of rolls due to having four and six rolls instead of two to keep in order.

The differences between the cluster and four-high, and preference for one or the other, are apparently small. The four-high mill is cheaper to install and in upkeep, and the working rolls are more easily accessible and adjustable. As might be expected, the cluster mill has greater rigidity, and when the rolls are definitely adjusted there is less chance of them coming out of line. The four-high mill, however, seems to be gaining the greater popularity, but the proportions of the rolls in these mills are a subject of considerable controversy. In America it is generally considered that the backing roll should be two-and-a-half times the diameter of the working roll. English and Continental practice is at present to make the proportion about twice or slightly less.

Fig. 2 shows a small cluster mill of standard design with working rolls 5 in. diameter and backing rolls 10 in. diameter. This is for use on strip below 0·050 in. thick, above which thickness the metal cannot be made to enter with a heavy pinch. The usual speed of a mill of this size is 60 ft. to 70 ft. per minute—above which speed difficulty is experienced with heating of the rolls. Fig. 3 shows a large four-high mill with 14 in. diameter × 48 in. face working rolls for use on material up to 0·25 in. thick. The backing rolls in this case are on flood bearings, giving greater rigidity and strength. A continuous wide hot strip mill at work in America rolls hot strip to 0·064in × 37 in. wide. The mills have 14 in. diameter working rolls and 32 in. diameter backing rolls running in roller bearings. The speed of rolling of backed-up mills has so far been very slow in Europe. As mentioned before, 60 ft. to 70 ft. per minute is normal. Mills have been installed running satisfactorily at 150 ft. per minute. In America these mills are running up to 450 ft. per minute on strip work, and it is probable that rolling speeds on backed-up mills will increase largely during the next few years.

In all mill designs the question of roll material is of considerable importance. Formerly the chilled cast-iron roll was standard practice, and for hot rolling this material is almost always used in England, as a hardened-steel roll would be liable to crack or break when heated-up in use. However, special steel rolls, not dead-hard, are now being introduced for hot rolling. Dead-hard rolls have been introduced during recent years for cold rolling. Special chrome steel, capable of being hardened to a hardness of 100 Sclerescope is being produced, and rolls of this material are being installed almost entirely for cold rolling. These rolls are not only harder than chilled cast iron, but keep a better surface, thus producing better metal, and there is less fear of breakage. While the material comprising the working roll must of necessity be hard, it is an advantage to make the backing rolls in multiple mills of slightly softer materials. For this purpose casehardened mild-steel rolls have been found satisfactory, and chilled iron rolls can be used ; but with the latter it is unwise to fit roller bearings, as this is a disadvantage to their use.

The relation between diameter and face of roll is important. For cold rolling it was customary until recently to make standard sizes of 20 in. diameter with 36 in. face, 16 in. diameter with 30 in. face, and 9 in. diameter with 17 in. face. Rolls were ground with considerable camber and adjustments made by means of emery and a stick. Different widths of metal were rolled in different positions, the operator securing the rolls to suit the particular width and gauge. Modern tendency in two-high mills is towards the stumpy roll ; standard sizes now being 10 in. diameter × 10 in. face, 14 in. diameter × 18 in. face, and 22 in. diameter × 24 in. face. The whole mill is in consequence

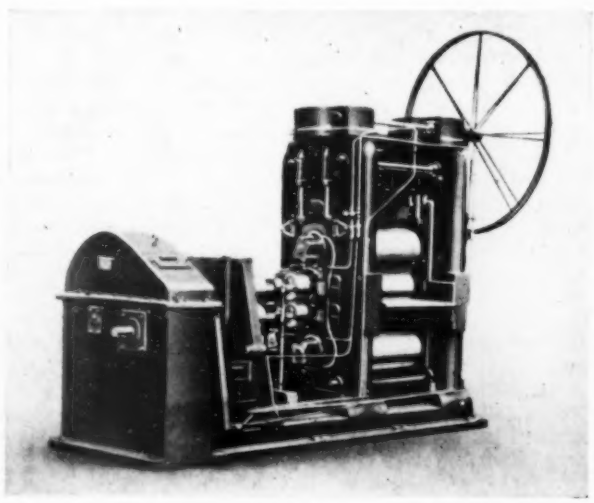


Fig. 3.—Four-high Sheet Mill with 14 in. dia. Backing Rolls and Flood Bearings.

a more rigid structure, and metal is always rolled in the same position on the rolls. The camber can be reduced and at high rolling speeds accurate gauge metal is produced. In the backed-up type mills the effect of a stumpy roll is produced by the backing-up rolls, and the face is usually much wider than the diameter. For hot rolling the

proportion is often as much as 3 to 1, but 2 to 1 can be considered usual.

The sizes and types of mills may be classified in four divisions—*i.e.*, hot and cold strip rolling of ferrous and non-ferrous metals. In the production of non-ferrous strip until quite recently hot rolling was rarely thought of. Copper was about the only non-ferrous metal hot rolled. It has been the customary English practice to cast brass in weights of between 60 and 80 lb. from 1 in. to 1¼ in. thick and wide depending on the final width. The brass is broken down from 1 in. to ½ in. or ⅜ in. in the breaking-down mill, usually 22 in. or 24 in. diameter rolls with about 30 in. face. It is then annealed and run down to about ⅛ in. on 16 in. or 20 in. mills; 14 in. or 12 in. mills deal with metal between ⅛ in. and 0·040, while further reduction involves 10 in. or 8 in. mills. This represents the most economical practice with two-high mills. The cluster or four-high mills being installed for rolling brass strip usually have working rolls half the diameter of the two-high mills, thus a 5-in. diameter working roll on a cluster mill is doing the same work as 10 in. diameter on a two-high mill. The sizes referred to are for an ordinary brass strip mill where 12 in. is probably the maximum width rolled, and 8 in. the usual width. As the width increases larger rolls have to be used for rigidity, and it is for this purpose that the four-high mill is definitely advantageous, as a small-diameter working roll can be used.

In regard to the speed of cold rolling, English and Continental practice has, until recently, been to run at from 60 ft. to 80 ft. per min. with heavy pinches up to 45 or 50% reduction in thickness, the speed being limited by the heating of the necks under heavy load. Recent mills installed in England and fitted with flood bearings are running up to 300 ft. per min, and taking as heavy passes as before. This represents a very important development. Contrary to expectations, the power consumed at the higher speeds is very little more than at the low speeds. It seems that after the initial resistance of the metal has been overcome and the flow commenced it carries on easily. The two-high mill can roll very accurately at 300 ft. per min. and take up 60% reduction in two passes before annealing. With the low-speed cluster and four-high mills a speed of 60 ft. per min. is accomplished, and three passes are necessary to get a reduction of 80%.

Steel strip is generally rolled hot down to about 0·060 in., and is then rolled down further cold, due to the detrimental effect of scale on the final material. The hot rolling of the strip is either carried out in a tandem train of mills known as a Morgan continuous mill for large production, or on a double-duo, three-high or ordinary two-high mill for smaller production. With the Morgan mill the billet comes straight from the furnace to a series of two-high mills with grooved rolls to suit the final section to be produced. It passes through vertical rolls to edge to size, and then into a train of two-high mills with flat rolls. The strip finishes at a speed in the neighbourhood of 3500 ft. per min., whence it passes on to a cooling table, fitted at entry with an oscillating device. The trouble with a mill of this type is to regulate the speeds and pinches of each set of rolls to ensure the strip does not break or pile up in one place. The speed of entry and pinch taken determine the speed of each following mill in the train and, therefore, great care must be taken with the regulation of each mill. This is usually done with variable-speed motors and elaborate electric control gear.

The cold rolling of steel strip is very similar to that of brass strip, except that such heavy pinches cannot be taken. Rolling the strip through a series of mills in tandem is becoming increasingly common, particularly in America.

It is in the cold rolling of wide steel strip that the four-high mill has been such an advance. Its use has made possible the rolling of 36 in. steel strip, a size not hitherto contemplated. The use of such strip is for automobile body work, large quantities of which are now used.

WELDING COPPER.

UNTIL recent years it was considered that the satisfactory welding of copper was an impossibility. The high thermal conductivity of the metal gave rise to grave practical difficulties, and even if these were overcome it was found that the copper became brittle by the action of the gases in the acetylene flame.

With the formation of Imperial Chemical Industries, Ltd., consisting of chemical manufacturers, who require welded copper vessels; copper manufacturers, who are naturally anxious to see copper placed on the same footing as the majority of other metals, as far as welding is concerned; and experts in welding processes generally, we have technical authorities who are interested in copper welding from three different points of view coming together.

As the result of research work carried out by these three groups in collaboration, a process for welding copper has now been evolved which renders the operation simple and safe, provided the correct materials are used. A demonstration of this welding was carried out by the Premier Electric Welding Co., Ltd., on Tuesday, April 29, at the Swansea works of British Copper Manufacturers, Ltd., a subsidiary company of Imperial Chemical Industries, Ltd.

At this demonstration, copper pipes were welded together without difficulty, and the joint subjected to severe flattening and bending tests, the results of which proved conclusively that the weld would withstand conditions of service as satisfactorily as the pipe itself. Sheets of copper were also joined together by the welding process, and it was shown that these would withstand a considerable amount of work and stretching—in fact, as much as the solid copper itself could be expected to withstand.

The welding of varnish pot seams was also demonstrated, a process which eliminated a great deal of troublesome riveting. It was observed that the welding operator worked quickly and as easily as if he were merely brazing the pieces together, and, after the weld had been made and trimmed, it was difficult to see where the joint occurred, whilst it had a tensile strength equal to that of rolled copper.

The demonstration indicated that the difficulties previously associated with the welding of copper had been overcome, and it is certain that there is a wide field in industry for the application of the process. Riveting will be largely eliminated, and vessels which previously had to be forged out of solid copper—a very expensive procedure—can now be built up by welding sections together. All this has been achieved by means of slight modifications in the technique of welding ferrous metals, by the use of copper alloy filler rod and flux of the appropriate type. The copper which has been developed for welding purposes is not attacked by the gases of the acetylene flame, and it is essential to use this copper if the weld is to be perfectly satisfactory. The copper is a modification of the tough pitch variety, supplied at the same price, but not inferior to it in any way—in fact, it might be expected to give better service generally. The filler rod, again, is of specially modified copper, which is very fluid when molten, and so runs well into the joint, leaving no air locks or gaps. It is essential to use this filler rod in order to obtain a homogeneous weld. The flux is used in order to hinder the formation of scale on the red-hot copper, as the scale prevents good metallic contact being obtained. It was further demonstrated that with an hour's practice a welder could acquire the technique of copper welding and produce sound joints as easily as he could with ferrous materials.

RESEARCH WORK AWARD.

A Medal awarded annually by the South Staffordshire Iron and Steel Institute for original research work has this year been awarded to Mr. J. V. Murray for his research work on the effect of Nickel upon the mechanical properties and micro-structures of White Heart Malleable Cast Iron.

Possibilities of Malleable Iron Castings

By W. J. Molineux.

Present and Future Possibilities are Discussed.

THERE is an ever-increasing demand in every sphere of modern life for small castings, for which malleable iron is eminently suitable, the essential requirements being cheapness, uniformity of quality, size, hardness, appearance, and durability. There are many competitors, and the malleable founder will have to explore every avenue in his search for a superior product and cheaper manufacturing methods if he is to increase his sales, or perhaps even maintain his present position. The most serious rivals of malleable iron are steel castings, forgings, aluminium-alloy castings, and other non-ferrous sand and die castings, and hot pressings, etc.

Steel castings would seem to be serious rivals to malleable iron, especially steels of the stainless variety, although their cost is perhaps the chief drawback to their more extensive use. We should, however, not lose sight of the fact that progress is continually being made in both the quality and uniformity of steel castings. A continued reduction in manufacturing costs can likewise be confidently expected, as improved methods of manufacture are adopted. As electric current is such an important item of cost in electric steel melting, any reduction in price will obviously influence the cost of the lighter castings in steel. Another very important point in favour of steel castings is the much shorter time required for their production, due mainly to the short heat-treatment period. At present price rules out almost entirely alloy steels of the stainless variety, except for special purposes where cost is of minor importance. It must not, however, be overlooked that the very valuable properties of these steels are so attractive to the engineer that no effort will be spared in an endeavour to produce at more competitive prices. The malleable founder can, however, take heart from the present unmistakable tendency of engineers, especially those engaged in the motor industry, to again turn to malleable iron for many component parts for which steel was but a short time ago specified. At least one large manufacturer does not use a single steel casting in the manufacture of his commercial vehicles. The reason for this is not far to seek. The malleable founder has spent much time and money on research work, and to-day the founders producing the best material have discarded the old rule-of-thumb methods, and every step in the process of manufacture is under the supervision of technically trained men, with the result that castings of a high standard of reliability and uniformity are regularly produced.

Although after the war steel forgings came very much into favour with engineers, especially in the motor trade, the malleable founder has not much cause for alarm, as the cost of dies is high, and only parts of comparatively simple design can be produced by drop forgings,whereas castings of the most complicated design are being made daily in malleable iron. There are well-defined uses for steel forgings for which malleable castings would be quite unsuitable. But where these circumstances do not exist, and the two materials are of equal suitability, malleable iron is frequently preferred on price. Also, reluctance to alter or redesign parts, because of the cost of new dies for drop forgings, tends to stagnation in design.

Sand castings, die castings, and hot pressings, in the various brasses and bronzes, each have important qualities which make them peculiarly suitable for certain purposes Here, again, where price alone is the deciding factor and a ductile ferrous material is equally suitable for the work in hand, malleable iron will generally be used.

Professor Turner, at a meeting some years ago, expressed the opinion that whereas the nineteenth century was the century of steel, the twentieth century may prove to be the century of aluminium. The recent history of the aluminium industry is one series of triumphs, and new uses are found daily for this metal in one or other of its simple or complex alloys. Here, certainly, will be found a serious rival, not only to malleable iron, but to cast iron and steel. Alloys of aluminium are almost unique in the variety of their treatment and uses. They can be cast into sand or dies either by gravity or under pressure ; rolled, forged, welded, pressed, and spun with comparative ease, and the product is generally a light ductile corrosion-resisting material of low cost that can be machined with ease.

The Future.

Having considered the present position of the malleable casting, let us now consider future prospects. In what way can the malleable founder still further improve and cheapen his product, and in other ways make it a material more attractive to the engineer ? It is not long since—having in mind the whiteheart casting—malleable iron was favoured by the engineer less than any other product of the foundry industry, and although he was prepared to admit that good malleable was equal to mild steel, he would tell you that bad malleable was worse than grey iron, and he was right. The up-to-date founder having altered all this must eradicate the deep-seated and well-merited suspicion of malleable iron, based on experience of the material of yesterday, by educating engineers and designers in the excellence of his material. He must advise on design of castings, small modifications being often of great assistance in the successful founding of malleable iron.

Advice must be given on the choice of the most suitable of the two malleables for the work in hand. The engineer should specify the material he requires and the tests necessary to ensure getting that material. This will safeguard him, and give the modern founder his well-merited advantage over the unscientific man.

What are the possibilities of reducing manufacturing costs ? For convenience this can be considered under three heads, namely, cost of moulding and handling of materials, melting costs, and annealing costs.

Moulding and Handling of Material.—Moulding machines are employed as efficiently in this branch as in any in the foundry industry, and it is difficult to see how this item of cost can be much reduced without some revolutionary change in moulding-machine design, which seems improbable. By much capital expenditure it would be possible in many cases to reduce unskilled labour charges by the installation of plant for the automatic and semi-automatic conveyance of materials such as sand, castings, metal, returns, etc. It has been stated that over 100 tons of material has to be moved during the production of 1 ton of castings. Here, surely, is food for thought. Much can also be done by the effective application of sand-reconditioning plant, with a consequent saving in labour and new sand.

Melting Costs.—In making whiteheart malleable the cupola is still the cheapest melting medium, and there seems little prospect of any immediate improvement on the cupola on the score of cheapness, in spite of its other drawbacks.

The cost of the special irons necessary for the production of whiteheart metal from the cupola is very high. In the case of blackheart malleable there is considerable variety in the choice of a furnace. A cupola used alone is unsuitable, chiefly on account of the non-uniformity of the metal produced. It is impossible, at least at present, to produce with regularity iron, low in carbon, silicon, and sulphur, of sufficiently high temperature to pour moulds.

The air-furnace is most in favour with blackheart founders as a melting medium, and all things considered it has many points in its favour, the chief of which is perhaps the regularity of the composition of the melt from day to day, due to the ease with which bath samples can be tested periodically until the whole is ready for tapping. Fuel costs are high when compared with the cupola, but with the advent of pulverised-fuel-fired furnaces marked economies are effected. Cheap grades of coal can be used and melting times reduced by this latter method of firing. With pulverised fuel the furnace can be got under heat quickly, and when the plant is running very little attention is required. The combustion conditions also can be regulated at will. Here, certainly, is a definite step towards cost reduction, which doubtless will be carried still further as pulverised plant and burners become more efficient.

It is well known that blackheart malleable has not in the past been made in large quantities in this country, because of the lack of irons low in silicon and sulphur for air-furnace melting. It is possible now, however, to obtain a material of proper composition from English iron-masters.

The electric furnace is most attractive for the making of malleable iron, although its melting and running costs are high, and difficulties in annealing are encountered, which are peculiar to metal from this type of furnace. It has, however, got several points in its favour; the charge can be built up from comparatively inexpensive raw materials, and the composition of the charge can be adjusted with ease and precision. The possibilities of this furnace for blackheart malleable production are great, especially when used in conjunction with other types of furnace, such as in the triplex process developed by W. C. Kranz in America, where a cupola and a converter are used in conjunction with an electric furnace. In this process the cupola being the cheap melting furnace is used for melting the charge; a part of which is transferred to a Bessemer converter for the reduction of the carbon, silicon, and manganese. The metal from both the cupola and converter is then taken to the arc furnace for finally heating and refining.

Although considerable capital expenditure is necessary for making blackheart malleable by this process, it has a great many points in its favour. The cupola charge can be made up of scrap and cheap pig irons, expensive irons being unnecessary. It will readily be seen that in this process three furnaces are used in a most suitable manner; the cupola, being the cheap melter, is used for melting purposes only. The reduction of silicon, carbon, etc., is more cheaply effected by oxidation in the converter, and the required amount of metal is therefore treated in that furnace. Again, the electric furnace is the furnace *par excellence* for superheating, refining, checking, and altering the composition of the heat before tapping and pouring into moulds.

Annealing Costs.—To satisfactorily anneal whiteheart malleable, the oven must be held at a temperature of nearly 1000° C. for about 100 hours, the total time for the annealing cycle being about 240 hours. In the case of blackheart the temperature is about 100° less, and the time at full temperature some 35 to 40 hours less; the full cycle occupying 180 to 200 hours. In both cases this is a costly operation, whether the furnace is fired with coal, pulverised fuel, or producer gas, and any economy in time will consequently cheapen and serve to make malleable iron more popular.

Here, certainly, is the happy hunting-ground for the research worker. A shortened malleablising period that would leave the physical properties unimpaired would be a boon indeed.

In America much time and thought have been given to the subject, and several founders now have continuous annealing plants. A most interesting departure from the usual annealing cycle has recently been made by the Canadian General Electric Company, the details of the process having been worked out at their Erie Foundry. By this process—only meagre particulars of which are yet to hand—the annealing oven is electrically heated, making possible the attainment of the precise temperatures necessary for success. Moreover, the castings are not packed in any way, thus dispensing with packing material, annealing boxes, and the labour required for packing and unpacking. Briefly, the process is as follows:—

Three ovens are used, into the first of which the hard castings are stacked on the bottom of the car, and the temperature raised sufficiently high to effect solid solution of the free cementite. The car and charge is then transferred to another oven and held at a temperature just below 750° C. for 4 hours, when the temperature is again lowered a few degrees, at which temperature it is held for 4 hours, when the step is again repeated. The castings are then put into the third oven for cooling, or are cooled in air or quenched. The average time for a 6-ton anneal is said to be about 30 hours. If this, or a similar annealing cycle, could be conducted at a cost less, or no higher, than the orthodox method, its effect on the industry would be far-reaching, and the time required for the production of castings would be about the same as for steel, and little more than for grey iron.

Conclusions.

To sum up, it can be stated with certainty that the future of malleable iron is very much in the hands of the founder himself, and the present indications certainly point to an increased demand, due chiefly to greater confidence in the material. This confidence has been obtained by the pioneer founders, who have produced a better article by the application of scientific principles to everyday practice.

It is obvious that in a process such as the making of malleable iron, dependent as it is on chemical change and physico-chemical changes at various temperatures, the men supervising these operations must have had some training in subjects that can be of assistance to them in adequately understanding the principles underlying these operations. In the appointment of such men to the proper positions certainly lies the road to success: in that first essential a uniform high-grade and reliable article with possibly improved physical properties.

An intelligent understanding of the basic differences of the two malleables must be aimed at, and the founder must not be afraid to state clearly to his customer the shortcomings of each.

Although of great importance to the consumer price is of secondary importance to quality; but in spite of the fact that malleable iron is still much cheaper than any other cast material of equal tenacity and ductility, much can still be accomplished in the way of cost reduction by further adoption in the average foundry of labour-saving machinery, modern melting equipment, more efficient annealing plant, etc. These reductions in production cost would, if carried into effect, benefit the consumer and, ultimately, the founder by making his product more popular.

METALLURGIA

The British Journal of Metals.

★ The source of all matter extracted from this Journal must be duly acknowledged; it is copyright. ★

Contributions suitable for the editorial pages are invited. Photographs and drawings suitable for reproduction are welcome. Contributions are paid for at the usual rates.

PRINCIPAL CONTENTS IN THIS ISSUE:

	Page
Heat-treatment, Electric Furnace, for Duralumin Sheet. By ROBERT J. ANDERSON, Met.E., D.Sc.	1–3
Chrome Plating and Anodic Oxidation	3
Strip Rolling Mills. By W. H. ROBERTSON, B.Sc.	4–6
Welding Copper	6
Possibilities of Malleable-iron Castings. By W. J. MOLINEUX. *Present and future possibilities are discussed.*	7–8
Declining Exports	10
Scientific Results and their Application	11
A.S.M.E. Fiftieth Anniversary	11
Correspondence	12
Chemical Composition and Mechanical Properties of Centrifugal Castings. By J. E. HURST	13–16
Standard Tin-base White Metal "B"	16
The Iron and Steel Institute. *A brief summary of papers presented at the annual meeting.*	17–21
Some Metallurgical Problems Connected with the Possible Use of Very High Steam Temperatures. By J. H. G. MONYPENNY, F. Inst.P.	22–25
FURTHER ALLOYS USED IN STEELMAKING	CHART
High-speed Steel Hacksaws. By J. H. BARBER, M.I.Mech.E.	25
The Influence of Technique on Research	26
Blast-furnace Practice and its Operation. By R. A. HACKING, B.Sc. *The use of higher blast temperatures—Theoretical considerations — Operating results—Practical difficulties—Future developments.*	27–28
Heat-resisting Cast Iron. By J. W. DONALDSON, D.Sc. *Finding a cast iron of suitable composition to resist growth and reduction in strength resulting from repeated heatings and coolings is the problem of the cast iron metallurgist.*	29–30
Reviews of Current Literature	31
Nitrogen Case-hardening of Steel by the Homo Method	32
Failure of a Crankshaft. By H. W. KEEBLE	35–36
Some Recent Inventions	33–34
Business Notes and News	37
Some Contracts	38
Iron and Steel Report	39
Ferro-alloy Report	39
The Copper Cut	39
Metal Prices	40

Subscription Rates for the British Isles - - - 24/- per annum, Post Free

FOREIGN SUBSCRIPTION RATES.

France	Fcs. 155	Canada	$6·20	Denmark	Kr. 22·80
Australia	25/-	Belgium	Belgas. 43·60	Norway	Kr. 22·80
New Zealand	25/-	Italy	Lit. 116·45	Sweden	Kr. 22·80
India	Rs. 17	Holland	Fls. 15·13	Finland	F.M. 245
United States of America	$6·10	Spain	Pes. 43·20	Japan	Yen 12·65
Mexico	$12·70	Switzerland	Fcs. 31·50		
Argentine	Gold $6·50	Czechoslovakia	C.K. 206·25		
Germany	R.M. 25·50	Jugoslavia	Din. 345		
Austria	Sch. 43·50	Roumania	Lei 1025		

All the rates are subject to change without notice, according to appreciation or depreciation of the exchange.

Published Monthly by the Proprietors, THE KENNEDY PRESS LIMITED, at Kennedy House, Liverpool Road, Deansgate, Manchester.

Telegrams: "Kenpred," Manchester. *Telephone: Central 0098.*

CONTENTS

METALLURGIA
THE BRITISH JOURNAL OF METALS.

Declining Exports

HOWEVER much it may be desirable to maintain a spirit of optimism regarding future prospects for British trade it is none the less necessary to acknowledge facts. There is no doubt that at the present time trade is in a deplorable condition. Even when allowance is made for the break in trade activity during the Easter period the Board of Trade returns for April present a depressing picture. The value of British exports sank to £46,861,461, which represents the lowest monthly figure recorded for several years past. The imports for the month, valued at £83,922,401, were nearly £10,000,000 less than in March, and £20,206,330 less than in April of last year. The decline in the value of British exports in the first four months of this year as compared with the corresponding period last year amounts to £30,418,578 and imports have reduced in value over a similar period by £42,673,696. If a decline of over £8,000,000 in re-exports is included, the decline in total exports on the four months' comparison comes to £38,567,939.

The depressed state of the textile industries is the cause of the biggest reduction in exports, and is also prominently reflected in the decline of imports. This unfortunate position of this industry in some measure can be attributed to the present unrest in India, and also to economic difficulties in Australia. The next largest decrease in exports was in iron and steel, which, including iron and steel manufactures, was over £1,000,000 less than April of last year. In order to indicate the adverse position of this trade a comparison with the position in 1913 shows rather an alarming state of affairs. In 1913 we imported 2,232,000 tons, and exported 4,968,000 tons; during the first quarter of this year 850,600 tons were imported as compared with 701,300 tons for the same period last year, and exported 983,800 tons in comparison with 1,232,700 tons in the first quarter of 1929.

An examination of these figures undoubtedly indicates that, relatively, the position of the iron and steel trade is worse than during a similar period last year, and, while it would be idle to suggest that it has a permanent significance, it is necessary to face facts. It is frequently stated that the cost of production is too high to enable our manufacturers to compete on equal terms with those on the Continent. Our production costs are said to be higher because working hours are shorter and wages higher than any Continental country, with the possible exception of Germany, as far as wages are concerned. Germany is usually cited as being able to compete more favourably than this country, and while there is certainly much truth in this assertion it does not seem to be due to lower production costs. Ton for ton and quality for quality, steel can be, and is, produced at works in this country and transported to the ship's side at a lower inclusive cost than in Germany. This is contrary to the generally accepted advantages of cheap production and transport that are supposed to operate in Germany. It must not be forgotten that the relative distances between ore and coal mines steel works and shipping ports differ considerably from those in this country. The average haulage distances in Germany for raw materials to works and finished products to docks is five times as long and three times more costly than in Great Britain. But in Germany the industries are organised as syndicates, and these work in harmony in order to facilitate exports. Production is maintained as near full capacity as possible, and whenever the home trade temporarily declines an extra effort is made to export by means of rebates, bounties, and subsidies. The export system is supported by national and local governments, the coal-owners, the iron-ore mining companies, the railway and shipping companies, as well as the iron and steel syndicates, and, in addition, import duties on competitive goods afford shelter to the iron, steel, engineering, and other manufacturing industries. Thus, the home market security facilitiates the promotion of production economies, and at the same time enables organisation that can concentrate on export. With a slackening of home trade the export trade is increased by means of various forms of subsidies which may range from a few marks per ton to as much as 84 marks per ton, and the British iron and steel industry feels the effect of this subsidised competition because imports are permitted free. The operation of the German exporting system is worthy of note, and as it has apparently been successfully employed, as shown by the improved returns since its inception, it may have some value in suggesting means for resuscitating industry in this country. The producing firms contribute to their syndicates. Standard prices are fixed for the home market, but the syndicate allow rebates in regard to all materials used in products for export. The exportation of products in the manufacture of which the syndicates' materials have been used also entitles the producer to a rebate. The amount of the rebate fluctuates with the state of the home trade; the more depressed it is the higher the rebate on exports, whereas with a strong home demand the rebate is reduced, or may be suspended entirely. This system enables products to be exported at a cost lower than the same product can be purchased in the home market, in addition, materials and products for export are carried on German railways at a lower rate than is customary for home use. In what direction are efforts being made to cope with the unbridled competition from abroad? A good deal has been said about rationalisation by the amalgamation of firms and the closing of apparently redundant works; but the installation of new and modernising of available plant to keep abreast of modern developments is a heavy drain upon what is, in the majority of instances, a sorely depleted reserve. It must be recognised that our industries are handicapped with heavy taxation in comparison with competing nations, and this additional cost must be borne by our products.

A suggested project for centralising particular branches of the iron and steel industry has much to commend it. The scheme is formulated with the idea of allocating to most suitable areas the production of definite grades of work covered by the industry in order to limit transport and ultimately reduce the cost of production. This would have the additional value of facilitating the concentration of each individual organisation on its particular product and would foster mass production methods. The organisation of the industry as indicated by rationalisation has this for its object, but is it sufficient to restore the industry to its former prosperity? The industry has been under a cloud for years, and the reorganisation efforts have not yet disseminated the gloom sufficient to enable us to view future prospects with optimism. Indeed, it is questionable

whether adequate progress can be made as long as surplus steel products of other countries are allowed to be dumped in this country at a cost lower than the cost of production. The problem bristles with difficulties which can only be reduced by taking into consideration the whole of the intricate features involved and acting in a manner that is best suited to our special needs, without reference to any political creed. This can be adequately done by the formation of an independent committee having powers to probe into the intricacies of the industry and to determine the means to be employed for its resuscitation. Probably the Sankey Report will assist in reducing the difficulties.

Scientific Results and their Application.

THE progress of engineering primarily depends upon the production of more reliable materials and new materials to meet conditions that exhaust the usefulness of existing materials, and it is only by persistent research that the demands of progress can be met. It is now fully recognised that in executing its functions of dealing with fundamental problems, the prime concern of a research department is the observation, investigation, and development of scientific advancement with a view to its industrial application. The problems not only concern materials, but all ancillary processes employed in the production of these materials. In this work valuable aid is rendered by the various scientific organisations in facilitating the presentation of papers at these various meetings. In this way the results of research on a wide variety of problems are disseminated in such a manner that is likely to result in appreciation of the work done. The Iron and Steel Institute is an instance of this kind. At the annual meeting, held early this month, the proceedings included the presentation of a very comprehensive series of reports on investigations dealing with a wide range of problems. These have been summarised, and are referred to in another part of this journal.

Among the most important of these papers is the result of work that has been proceeding over a long period in connection with the investigation of alloys for use at high temperatures. Former investigations have clearly established the fact that, even at comparatively low temperatures and stresses, steels must not be regarded as permanent and elastic materials, and investigational work on the subject has advanced as a result of the work performed at the National Physical Laboratory.

In view of the demands made by the engineer for metals to withstand relatively high temperatures the work done has a direct application to industrial requirements, and will assist the manufacturers in some measure in complying with the new factors now entering into specifications.

Practically all the papers presented at this meeting have a direct bearing on industrial problems, and mention may be made of another phase of research work dealing with the blast furnace. Investigations in the problems associated with this production unit have been in progress over a period of many years, and the report of an experimental inquiry into the interaction of gases and ore in the blast furnaces indicates the difficult character of this work. To be of real value in its application to blast-furnace practice it is essential to have the co-operation of all blast-furnace people in supplying data relating to the material in the furnace at different temperatures and operating under standard conditions. No doubt Professor Bone, in introducing the paper, was perfectly justified in asking the members of the Institute whether they were really interested in work of this kind. He extended an invitation to all interested in blast-furnace problems to visit the laboratory and see the work that was being done and discuss it. At present, he said, there were no data as to the smelting of British ores under standard conditions, and, in order to obtain those data, more co-operation than had hitherto existed with blast-furnace people was essential. Until data were obtained, he continued, they were largely talking in the air as to the application to blast-furnace practice of the scientific results obtained in the laboratory.

A.S.M.E. Fiftieth Anniversary.

THE international character of engineering was successfully demonstrated at the fiftieth annual meeting of the American Society of Mechanical Engineers. The occasion was made memorable by the presentation of special Fiftieth Anniversary Medals to 16 representatives from different countries, each recipient being called upon to prepare, with such assistance as his countrymen could give him, a monograph covering the humanistic aspects of engineering in his native land. The historical celebrations took place at the Society's headquarters in New York, during which a pilgrimage was made to Hoboken, N.Y., in order to view, in the original assembly hall at Steven's Institute, where the initial meeting of the Society was held, a pageant depicting the growth of "control."

A bronze tablet commemorating the anniversary was unveiled at the opening ceremony by John Sweet, a grandnephew of a founder of the Society. The design of the tablet is similar to that which decorates one side of the anniversary medal, and in symbolic language expresses the optimistic philosophy of the engineer which is indicated by the inscription "What is not yet, may be."

Impressive functions took place in Washington. Following the welcoming assembly addresses were delivered in which the monographs, dealing with the humanistic aspects of engineering, were summarised by their authors or representatives. The British monograph was summarised in an address by its author, Mr. Loughnan St. L. Pendred, President of the Institute of Mechanical Engineers, in which he stated that the influence of mechanical engineering was not always good in its effect upon home life of the people. "It was the engineer's duty," he said, "to increase man's comfort and well-being."

The presentation of anniversary medals was made memorable, not only because the recipients of the awards were distinguished engineers, but also because the chief diplomatic officer of each country presented to the Society the engineer selected for this honour by the engineering profession of his country. Mr. Loughnan St. L. Pendred was presented by His Excellency Sir Ronald Lindsay, Ambassador to the United States. Each ambassador was presented to Mr. Conrad N. Lauer, who acted as chairman, and, in turn, presented the medalist. After a brief address by Mr. Lauer citing distinguished achievements of each recipient, the anniversary medal in bronze was presented and a gold replica of the medal pinned to the medalist's coat.

The whole ceremony was impressive, and these celebrations of the A.S.M.E. will not easily be forgotten by those who were fortunate enough to be present at the various functions.

Forthcoming Meetings

On Friday, May 30, Mr. H. R. Ricardo, A.M.Inst.C.E., M.I.A.E., F.R.Ae.S., will deliver the eighteenth Wilbur Wright Memorial Lecture before the Royal Aeronautical Society. The title of the lecture will be "The Development and Progress of Aircraft Engines," and it will be delivered at 6-30 p.m. at the Royal Society of Arts, 18, John Street, Adelphi, W.C. 2.

The Annual Conference of the Institute of British Foundrymen is to be held at Middlesbrough, from June 17 to 20 inclusive, and among the papers to be presented will be exchange papers as follows:—

American Exchange Paper.—"Developments in the Use of Briquetted Borings for Cupola Melting," by F. J. Walls, Pontiac, Michigan.

French Exchange Paper.—"The Making of Iron Castings for Heating Apparatus, Stoves, and for General Building Purposes," by H. P. Magdelenat, Vice-President, Association Technique de Fonderie a Paris.

Belgian Exchange Paper.—"The Preparation of Materials for the Converter when Used for Steel Castings," by J. Leonard, Ingenieur A.I.Liege, President of the Association Technique de Fonderie de Belgique, (Hon. member) Institute of British Foundrymen.

Correspondence.

To the Editor, METALLURGIA.

Dear Sir,—In connection with your correspondence on the subject of sand-blast shot, I have some experience of this manufacture by a somewhat different method to that which your correspondent is using. I fully appreciate the necessity for the hottest possible molten metal. I do not quite see how it would be practicable to use a brick in the manner suggested.

It may be that the requisite metal temperature is a matter of overhauling their cupola. This work is very much like tuning up a motor-car engine, in that it is difficult to give exact instructions. Briefly, this may be dealt with in the following manner. After reviewing the grade and quality of the coke, bearing in mind the desire for high temperature, the height of the bed should be checked to determine whether the best height has been adopted. At the same time, the volume of air should be checked for the particular coke consumption and the size of the tuyeres and pressure of air supply.

Adjustments in the air supply—volume and pressure, together with adjustment of the height of bed—give the temperatures they desire. If this fails, then a construction in the lining at the lower end of the melting zone, with a suitable adjustment of air supply—to burn the same quantity of coke—may be necessary. It is possible to melt very hot in suitably designed constricted cupolas.

It is difficult to advise exactly in the absence of any detailed information of their present practice. If your correspondent cares to submit fuller details, I would be interested in going into the matter further.

I would suggest to them that a suitable metal, tough, and exceptionally hard, would be found in the high manganese hematite. The high carbon, together with the high manganese, would give the desired results. This would not involve any increase in price. Messrs. Bradley and Foster would supply this material.—Yours faithfully,

METALLURGICAL CORRESPONDENT.

To the Editor, METALLURGIA.

Dear Sir,—Having seen in your March periodical an article by Walter Lister, I am sorry to say that he is wrong *re* rimmed in steel. Rimmed-in steel is not cauliflower tops, nor is it an unsightly mess at the top. Rimmed-in steel is smooth at the top; does not rise at all. If it does rise it has not been made properly.

I may say that the best steel for sheets is made from rimmed-in steel. Armco steel is rimmed-in. I think most of the latter is coming from America, where they have been rimming steel for a good many years. They also rim steel on the Continent.

I may say as a steelworker, that the best steel for sheets is rimmed-in steel, not killed steel, or dead steel, as is stated in the article.—Yours truly,

J. P. WALTERS.

To the Editor, METALLURGIA.

Dear Sir,—I much appreciate Mr. Walters' remarks in reference to my observations on "Rimmed-in Steel" and quite agree with him that a careless wording of the text may have given an erroneous impression to many readers.

What I meant to convey was, that much steel of "the rimmed-in variety," does not rim-in at all, but rises in the mould with "cauliflower tops," which is "an unsightly mess." This, of course, is due to faulty working of the charge.

In order to obtain an ingot which will allow the minimum of discard due to pipe, and also be soft enough for deep-stamping purposes, it is necessary to tap dead soft and with very little silicon addition. Therefore, the steel must not be "killed" in the ladle; it must be made in the furnace; and it must be made in such a way that it will not set "dead" in the moulds, nor go to the other extreme and rise with cauliflower tops. It must exhibit just sufficient liveliness to delay solidification somewhat. As the freezing process proceeds from the outside edge of the ingot, gases are evolved from the still-liquid portion. This causes a succession of "rims," narrowing in diameter towards the centre. This is called "rimming" or "rimmed-in" steel, and is the best material for the manufacture of sheets.

To make it successfully, it is largely a matter of slag control. The bath must first be entirely de-oxidised and then given sufficient time to allow the consequent non-metallic inclusions to rise and pass into the slag. A certain amount of FeO must then be allowed to diffuse from the slag into the metal. This calls for great skill on the part of the steelmaker in judging the viscosity of the slag so that the previous work of de-oxidation is not nullified. Too great a degree of FeO diffusion results in cauliflower tops. It may happen that only the last portion of the charge will rise and the first portion rim-in successfully.

In any case, ingots in this condition must necessarily be of inferior quality and fit only for low-grade classes of steel. But, as I stated in my remarks, even these can be made more presentable and profitable by preventing the unsightly rise by means of a lid or piece of scrap plate.

Hoping this will make the matter perfectly clear,—
—Yours faithfully,

WALTER LISTER.

To the Editor, METALLURGIA.

Dear Sir,—In an article entitled "The Development of Electro Deposition," in the April number of METALLURGIA, Mr. R. Mordaunt makes the rather astounding statement that electro-galvanised steel wire has superseded to a large extent the hot galvanised product. I think he must be labouring under a misapprehension, for the weekly production of hot galvanised wire in this country is certainly not less than 6,000 tons, while a production of 200 tons per week is the highest conceivable maximum for electro-galvanised wire.

With regard to the so-called "rustless fly-screen wire cloth," this can be, and most often is, woven from hot galvanised wire, and it is quite untrue to say that it is a product which it is only practical to produce by zinc plating.—Yours faithfully,

For RYLANDS BROTHERS, LTD.,
GEOFFREY K. RYLANDS,
Warrington. General Works Manager.

To the Editor, METALLURGIA.

Dear Sir,—I am obliged by your correspondent's remarks regarding the production of electro-galvanised and hot galvanised steel wire, and sincerely regret the error. This is due to the accidental omission of the word "America" from my manuscript. Your correspondent is quite right in stating that the weekly production of hot galvanized wire in this country is not less than 6,000 tons, while the production of electro-galvanised wire is not above 200 tons. In America these figures are reversed, and the ratio is indeed much less—hence the statement should have read: "In America electro-galvanised steel wire has superseded to a large extent the hot-galvanised product . . ." The Americans contend that the production of zinc-plating of rustless fly-screen wire cloth is more homeogeneous; a good deal is certainly woven here from hot galvanised wire.—Yours very truly, R. MORDAUNT.

[We are surprised at the amount of electro-galvanised steel wire which our correspondent states is being produced in America, although we are informed that this process has been developed with some success for the coating of fly-screen wire cloth.—ED.]

We have been informed that at Field Broughton, Lancashire, on Easter Tuesday, the wedding took place of Mr. Colin Presswood, B.A., F.G.S., Manager of the Worksop Works of General Refractories, Ltd., and Miss Winifred Whinnerah, M.A., who has been for some time on the Staff of the Woodhouse Secondary School.

Chemical Composition and Mechanical Properties of Centrifugal Castings.

By J. E. Hurst.

IN commercial practice the centrifugal method of producing castings in cast iron is applied to cast-iron pipes for the conveyance of water and gas, and to cast-iron drums or cylinders used for the manufacture of piston rings, cylinder liners, and castings of like nature. The importance of the chemical composition as a factor in the behaviour of the castings in service is much greater in the latter case than in the former. The chemical composition of the centrifugal cast-iron pipe made by various processes in different parts of the world varies somewhat. A summary of published analyses taken from various sources is given in Table I. In the case of the Lavaud pipe, the analyses are taken on the pipe after annealing.

The chemical composition of centrifugal castings for automobile and aircraft piston ring drums is laid down in the British Engineering Standards Association's Specification No. 5004, and the Aircraft Material Specification 4 K 6. The composition limits called for in the latter specification are as follows :—

Total carbon	Not more than 3·50%
Combined carbon	Between 0·45 and 0·80%
Silicon	Between 1·80 and 2·50%
Sulphur	Not more than 0·12%
Phosphorus	Not more than 1·00%
Manganese.....	Between 0·40 and 1·20%

For larger cylinder liners of greater radial thickness than castings covered by the above specifications, material of lower silicon content is manufactured by the centrifugal process. Where required, alloy cast irons containing nickel and chromium, either singly or jointly, are also cast by the process. For piston ring material and general cylinder liner work annealing to remove chill is not permissible, and the castings must be produced directly grey and machinable. It is for this reason that careful control of the composition, particularly the silicon content, is primarily necessary. Furthermore for automobile and aircraft piston rings it has been found desirable that the combined carbon contents should be maintained above the minimum value laid down in the specification. For this careful control of the remainder of the composition is found to be necessary. As the properties required of piston rings are in a large measure dependent upon the chemical composition, uniformity of properties demands strict uniformity of chemical composition. In this respect the centrifugal process lends itself admirably to the strict control necessary to secure such uniformity, and in practice this is carefully carried out.

The fact that the molten metal, when in the rotating mould, is subjected for a time to the influence of centrifugal action adds considerable interest to the study of the distribution of the various constituents across the radial thickness of the casting. The results of a study of the distribution of the various elements across the radial thickness of 12 in. diameter and 8 in. diameter Stanton-Lavaud spun pipes have been given by Fox and Wilson.* These results have been determined presumably on the castings after annealing, and they are illustrated in Fig. 1. A further similar investigation has been carried out by Pardun of Gelsenkirchen.† These results are embodied in the diagrams given in Fig. 2. In this instance the results have been determined on unannealed castings. The results of Fox and Wilson and Pardun agree that the silicon is more or less uniformly distributed throughout the section, and unaffected by the centrifugal action. Both manganese and sulphur show a marked segregation towards the inside surface, and are found to be concentrated in the extreme inside layers. The results of the phosphorus determinations show that this has the tendency to be concentrated towards the outer layers, and a distinct zone of higher phosphorus content is disclosed close to, but definitely underneath, the outermost layers. In the case of the carbon contents, the results of these two investigations differ. Fox and Wilson show a slight tendency for the total carbon contents to increase in the direction of the inside of the casting, whilst Pardun's results show exactly the opposite effect. Similarly with the graphite, the marked increase in the direction of the inside surface is to be compared with Pardun's results, in which the graphite behaves very similarly to the phosphorus.

The sulphide segregation is undoubtedly due to the centrifugal action on the manganese sulphide particles. Chemical analyses taken from the segregated portion and the body of the casting gave the following results :—

	Manganese. %	Sulphur. %
Segregated portion	0·60	0·23
Body of casting	0·33	0·06

The excess of manganese and sulphur in the segregated portion—viz., 0·27% manganese and 0·17% sulphur—correspond sufficiently closely to the requirements of the formula MnS, as could be expected under the circumstances. The movement of manganese sulphide under these conditions is very clear evidence of the insolubility of this compound in molten cast-iron under the temperature conditions prevailing. There is no clear evidence of any tendency of movement of the carbon under the influence of the centrifugal force. The difference in the results of Fox and Wilson and Pardun may be explained partially by the fact that the former analyses were made on the annealed material. Furthermore, the effects of primary segregation may be expected to be prominent under the conditions of casting in metal moulds, entirely independent of any consideration of centrifugal action. This aspect of the matter has not been sufficiently studied to warrant further discussion at present. Suffice it to say that the irregularities in distribution of the carbon constituent noted in the above experiments can be removed almost entirely by adjustment of the chemical composition ; a fact which goes to prove that the irregularities noticed are not due to the centrifugal action. It is only right to record that Pardun, in discussing his results, states that " it was found that the conditions of casting, such as increasing the speed of rotation, varying composition, and varying casting temperature, have no logical influence on segregation."

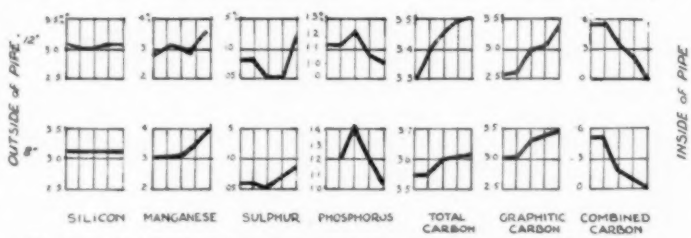


Fig. 1.—Distribution of the Elements in Stanton-Lavaud Spun Iron Pipes (Fox and Wilson).

* I.B.F., Glasgow, December 12, 1925.

† *Stahl und Eisen*, No. 35, 1924.

Microstructure.—The structural characteristics of centrifugally cast iron vary naturally according to the characteristics of the particular process by which it is made. Obviously, there is a difference in structural character between cast iron spun in metal moulds and that spun in sand moulds. This difference is very noticeable in the appearance of the free carbon. Fig. 3 shows the character and distribution of the graphite typical of centrifugal castings made in metal moulds, whilst Fig. 4 is typical of the graphite distribution of cast iron, cast centrifugally in a sand mould. Both photographs are taken at the same magnification, and the exceptionally fine form of the graphite in the metal mould centrifugal casting can be compared with the sand mould centrifugal casting. Incidentally, it is worth while pointing out at this stage that the degree of fineness of the graphite is not in itself directly related to the strength properties of the material. Of the two examples above illustrated, the one having the coarser graphite structure is by far the stronger of the two, as measured by the tensile strength.

The etched structures of the same two samples at a higher magnification are illustrated in Figs. 5 and 6. These should be considered in conjunction with the chemical analyses of the two samples given below :—

	Fig. 3. Ref. 21459 B. %		Fig. 4. Ref. 21459 C. %
Total carbon	3·22	..	3·25
Combined carbon	0·57	..	0·89
Graphite	2·65	..	2·36
Silicon	2·02	..	1·58
Manganese	0·77	..	0·82
Sulphur	0·08	..	0·095
Phosphorus	0·72	..	0·66

In Fig. 3, in addition to the phosphide eutectic, the ground mass structure consists of pearlite and more or less defined colonies of ferrite. In the ground mass structure of Fig. 4 there is no ferrite, the whole structure consisting of pearlite, some cementite, and the phosphide eutectic. This difference in structural constituents is largely due to the lower silicon content, and of course has a large influence in the higher strength properties of this sample. In both cases the closeness and fineness of the different constituents will be noticed. This is characteristic of castings made by the centrifugal process, and is, of course, reflected in the closeness of the fracture of such castings.

Mechanical Properties.—The investigations of the mechanical properties of centrifugal castings have been carried out naturally with an eye to conditions of service of the particular castings. For example, the conditions of service of cast-iron pipes have determined the character of the tests applied to this material cast centrifugally, and similarly, in the case of cast iron intended for piston rings. In a number of cases the inability of casting test-bars of the ordinary type by the centrifugal process has led to the modification of the ordinary test methods and their adaptation to special forms of test pieces cut from the castings.

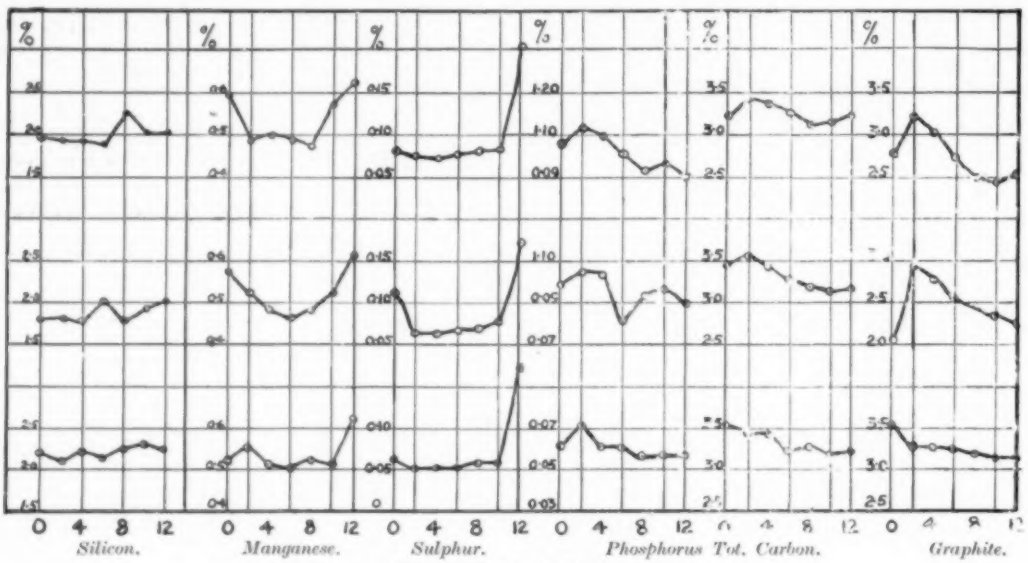


Fig. 2.—Pardun's Results.

Quite a number of thorough investigations have been made both in this country and abroad into the mechanical strength properties of centrifugal cast-iron pipe. In all cases these investigations have been concerned both with the intrinsic properties of the material and the properties of the casting as a whole. The most important of these investigations are those by Fox and Wilson of the Stanton Co. in this country, and those of Menefee and White and Talbot and Richart in America.* In the exhaustive series of tests undertaken by Fox and Wilson, full-scale tests were conducted on paper, in addition to the tests on the material, and the most important of their figures are abstracted in the following :—

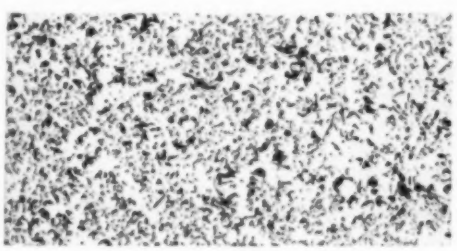


Fig. 3. Unetched structure of centrifugal castings made in metal mould. No annealing × 50 Diams.

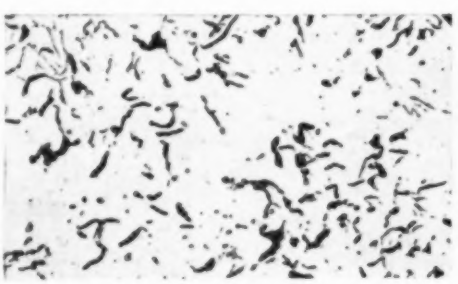


Fig. 4. Unetched structure of centrifugal castings made in sand mould. No annealing × 50 Diams.

* Fox and Wilson, I.B.F., Proceeding, 1925-26.
Menefee and White, Univ. Michigan, Ann Arbor, No. 4, 1928.
Talbot and Richart, Proc. Am. Soc., Testing Materials, Vol. 26, Part 2, page 185.

Bursting Pressure.—The ultimate bursting pressure was determined hydraulically on British Standard length pipes, and the comparative tensile strengths determined from the bursting pressures. In making such tests on long length pipes the comparatively high end pressure necessary to maintain the joints subjects the casting to considerable longitudinal stress, with a consequent lowering of the tensile strength as derived from these pressures. To demonstrate their influence, Fox and Wilson carried out a series of tests on shorter lengths of pipe—viz., 5 ft. lengths. Their results are given in the following table, and the tensile figures are calculated from the bursting pressures by the application of the formula :—

$$ft = \left(\frac{(R_1^2) + (R_2)^2}{(R_1^2) - (R_2)^2}\right) \times P$$

Where ft = tensile strength in pounds per square inch ; R_1 = outside radius of pipe in inches ; R_2 = inside radius of pipe in inches ; P = the hydraulic bursting pressure in pounds per square inch.

Bursting Pressures.					Calculated Tensile Strengths.	
Diam. of Pipe.	Average Thickn'ss.	12-ft. Lengths.	Average Thickn'ss.	5-ft. Lengths.	12-ft. Lengths.	5-ft. Lengths.
In.	In.	Lb. per Sq. In.	In.	Lb. per Sq. In.	Tons per Sq. In.	Tons per Sq. In.
6	0·367	2800	0·351	3200	12·75	14·51
8	0·354	2500	0·398	2850	13·30	14·41
10	0·427	2250	0·444	2650	13·58	14·45
12	0·442	2000	0·448	2300	13·46	14·65

For comparative purposes their determinations of 5-ft. lengths of standard sand-cast pipe are given in the following table :—

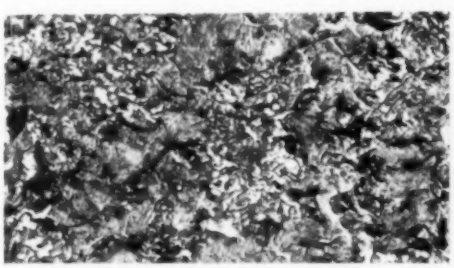


Fig. 5. Etched structure of Fig. 3. Etched in Picric Acid. × 200 Dias.

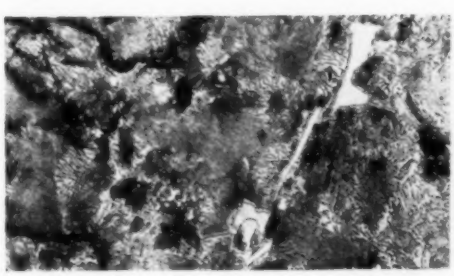


Fig. 6. Etched Structure of Fig. 4. Etched Picric Acid. × 200 Dias.

Bursting Pressure.			Tensile.
Diameter of Pipe.	Average Thickness.	5-ft. Length.	Calculated.
In.	In.	Lb. per Sq. In.	Tons per Sq. In.
6	0·424	2,050	6·94
8	0·481	2,200	8·87
10	0·507	2,050	9·58
12	0·545	1,550	8·04

External Collapsing Pressure (Line Load).—The external collapsing pressure under diametral loading applied along a line of contact was determined as a modulus of rupture, calculated in the following manner :—

$$M = \frac{6}{2\pi} \times \frac{\{P \times (D_1 - t)\}}{b + {}^2}$$

Where M = modulus of rupture in pounds per square inch ; P = load applied in pounds ; t = thickness of pipe in inches ; b = length of pipe in inches.

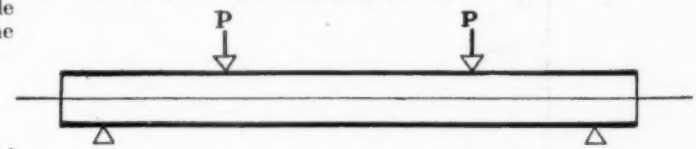


Fig. 7. Method of Traverse Loading Pipes.

The results obtained are given in the following table :—

Modulus of Rupture (External Pressure).

Diameter of Pipe.	Thickness of Pipe.	Load per Foot.	Modulus of Rupture.
In.	In.	Tons.	
4	0·383	8·56	60,060
6	0·379	6·72	54,767
8	0·394	5·47	53,595
10	0·442	5·78	55,257
12	0·441	4·46	52,081

Transverse Bending Tests on Pipes.—The transverse system of loading for this test as adopted by Fox and Wilson is indicated in the diagram, Fig. 8. The deflection was measured at the points of application of the load, and the deflection at the centre of the tested length was calculated from these observations. The transverse loading of a hollow cylindrical pipe in this manner has the merit of reducing the errors arising from the deformation of the pipe in its cross-sectional plane. Both the modulus of elasticity and the modulus of rupture were determined in the Fox and Wilson experiments. The modulus of elasticity was calculated from the observed deflection at a load value of approximately 25% of the breaking load.

The modulus of elasticity E was calculated from the formula :—

Deflection at point of application of load

$$= \frac{Pa^2}{12\,E\,I}(3\,L - 4a)$$

Where P = load in pounds ; I = moment of inertia ; L = distance between supports in inches ; a = half the difference between the distance between the points of application and the distance between the supports.

The value of the moment of inertia is determined from the relation—

$$I = \frac{\pi}{64}(D_1^4 - D_2^4)$$

Where D_1 and D_2 are the outside and inside diameter of the pipe respectively.

The modulus of rupture was calculated by means of the relation—

$$M_R = \frac{Pa}{2} \times \frac{32\,D_1}{\pi(D_1^4) - (D_2^4)}$$

And in the experiments where (a) equals 36 in., this formula becomes—

$$M = \frac{183{\cdot}5 \times P \times D_1}{D_1^4 - D_2^4}$$

maintaining the same nomenclature as in previous equations. The results obtained on centrifugal cast pipes are

compared with those obtained from sand-cast pipes in the following table :—

TRANSVERSE BENDING TESTS ON PIPES.

Diameter of Pipe in In.	Thickness of Pipe. In.	Breaking Load. Lb.	Maximum Deflection at Centre. In.	Modulus of Rupture Lb. per Sq. In.	Modulus of Elasticity. Lb. per Sq. In.
		Centrifugal Cast.			
4	0·320	14,900	2·11	53,000	17,350,000
6	0·391	31,400	1·13	45,000	16,850,000
8	0·381	50,400	0·80	41,000	16,910,000
10	0·373	77,300	0·82	41,400	12,700,000
12	0·437	103,000	0·64	34,950	11,290,000
		Sand Cast.			
4	0·432	7,560	1·20	23,200	11,400,000
6	0·454	21,000	0·97	27,200	11,930,000
8	0·513	33,600	0·62	21,600	11,150,000
10	0·615	76,100	0·64	26,600	10,650,000
12	0·603	100,800	0·55	25,600	9,560,000

The tests made on centrifugally cast material cut from centrifugal cast pipes include the following :—

Tensile tests.
Ring tests.
Transverse tests.
Brinell hardness tests.
Shock or impact tests.

In comparing the results of these tests made by different investigators, it is essential to bear in mind the possibility of difference in composition of the material tested.

Tensile Tests.—Direct tensile test-pieces cut longitudinally from Stanton-spun pipes are compared with similar test-pieces cut from their own sand-cast pipes in the following table :—

Diameter of Pipe. In.	Tensile Strength. Tons per Sq. In. Spun Cast.	Sand Cast.
4	19·98	10·58
6	19·10	10·71
8	18·43	11·00
10	18·05	11·65
12	18·00	10·90
Mean	18·71	10·37

The chemical composition of the centrifugal cast pipes is approximately that given in Table I. The chemical composition of the sand-cast pipes is that used normally by the Stanton firm for sand-cast pipes, and complying with the B.E.S.A. specification for cast-iron pipes, calling for a tensile test of 9½ tons per square inch.

The average tensile results obtained by Menefee and White on material cut from 6 in. and 8 in. centrifugal cast pipes made in America is given as 15 tons and 14 tons per square inch respectively, whilst the average results obtained from sand-cast pipes of the same diameters in the same series of tests was 9 tons per square inch.

Transverse Tests.—Transverse tests on strips cut longitudinally from pipes and supported during the tests on centres 12 in. apart were made by Fox and Wilson. The section of the bars, being a segmental portion of the cylinder, had curved sides and a correction factor was applied to the usual formula to take this into consideration when calculating the moduli of rupture and elasticity. The formulæ and the corrective factor for (t) used are given below, together with the comparative results of centrifugal cast and sand-cast material.

$$\text{Modulus of rupture} = \frac{3 \times P \times L}{2\,b\,t^2}$$

$$\text{Modulus of elasticity} = \frac{P \times L^3}{4\,b\,t^3\delta}$$

$$\text{Corrective factor for } (t) = 1 + \frac{b^2}{10\,R_1\,R_2}$$

Where P = load in pounds; L = length between supports in inches; δ = deflection in inches; t = thickness in inches; b = breadth in inches; R_1 = outer radius in inches; R_2 = inner radius in inches.

The average results for moduli of rupture and elasticity from a number of tests are as follows :—

	Centrifugal Cast.	Sand Cast.
Modulus of rupture ..	597,68 ..	45,025
Modulus of elasticity	15,870,086 ..	13,910,000

The average moduli of rupture are equivalent to breaking loads on the standard 2 in. × 1 in. × 36 in. standard bar of 41·5 cwt. and 28·5 cwt. on centrifugal cast and sand-cast material respectively.

(To be continued.)

TABLE I.

CHEMICAL ANALYSES OF CENTRIFUGAL CAST-IRON PIPE.

Process.	Operating at	Authority.	Reference.	Tot. C %	Gr %	CC %	Si %	Mn %	S %	P %
Lavaud	Stanton, Eng.	Fox & Wilson		3·5	—	—	3·00	0·35	0·05	1·20
Lavaud	Toronto, Can.	Gillespie	"Can. Eng.," May 12/21	3·45	—	—	2·48	0·49	0·053	0·563
Lavaud	U.S.A.	Kreutzberg	"Foundry," Sept. 15/23	—	—	—	2·50	0·60	0·06	0·70
Lavaud	Germany	Purdon	"F.T.J.," Dec. 4/24	3·50	—	—	2·25	0·70	0·06	0·90
Lavaud	U.S.A.	Menefee & White	Univ. Mich.: Reprint Series No. 4, 1928	3·47 3·66	3·14 3·49	0·09 0·46	1·84 2·73	0·38 0·76	0·029 0·114	0·626 0·800
Sand Spun	U.S.A.	Mackenzie	"Amer. I. & S.I., Oct., 1927	3·50	2·75	0·75	1·60	—	—	0·70
Sand Spun	U.S.A.	Avey	"Foundry," Jan. 1/27	3·40 3·65	—	—	1·50 2·00	0·40 0·60	0·06 0·075	0·70 0·90
Possenti	Italy	Guerrini	"Foundry," Oct. 15/28	3·20	2·80	0·40	2·33	0·73	0·064	1·28

British Chemical Standard Tin-Base White Metal "B"

THE fourth of the series of non-ferrous standard analysed samples is now ready for issue.

The analysis is as follows :—

Tin	84·0
Antimony	7·52
Copper	4·03
Lead	3·86
Zinc	0·40
Iron	0·05
Arsenic	0·04

For many years non-ferrous chemists have wished to have a standard of this kind to guide them in the analysis of tin-base bearing metals, on account of working to specifications, confirming the quantity of the high-priced metals in the alloy and settling disputes. The analyses have been made by twelve chemists experienced in testing this class of alloy. The list includes a Government Department, also several referee chemists, manufacturers, and users. An important feature of the certificates of analysis is the outline of methods used by the different analysts.

The standard is available to anyone at a price based on ultimately covering the cost of preparing and issuing it. The three usual sizes—viz., 50-grm., 100-grm., and 500-grm. bottles—are provided together with certificate and methods with each sample. Further particulars may be obtained from British Chemical Standard Headquarters, 3, Wilson, Street, Middlesbrough.

The Iron and Steel Institute

At the sixty-first annual general meeting of the Iron and Steel Institute, at which the President, Professor Henry Louis, was in the chair, the agenda included a comprehensive list of papers, a brief summary of which we publish, together with references to the discussions which followed the reading of some of the papers.

Some Alloys for Use at High Temperatures.

By W. BOSENHAIN, B.A., D.Sc., F.R.S.: and
C. H. M. JENKINS, B.Sc., A.R.S.M.

THE investigations described and the experimental data given in Parts I. and II. of this paper are very comprehensive. They have been carried out at the National Physical Laboratory, under the auspices of the Committee on the Behaviour of Materials at High Temperatures of the Department of Scientific and Industrial Research, for the Engineering Co-ordinating Research Board, and later for the Metallurgy Research Board of the D.S.I.R. It was desired to find, if possible, alloys which should satisfy more fully than those already available the present and probable future requirements of engineering practice for materials possessing great strength—and particularly resistance to "creep" under prolonged loading,—at temperatures between 650° and 800° C.

The alloys of nickel and chromium were first selected for study, and the present paper describes the results of this investigation, which was conducted concurrently with an extensive study of the high-temperature properties of existing materials, which has furnished valuable data for comparison. In this investigation a large number of alloys containing as much as 60 per cent. of chromium, with various proportions of nickel have been examined. The experimental data regarding these alloys are for convenience classified into three sections.

The alloys were tested in regard to their endurance under prolonged load at 800° C., with the exception of some simple nickel-chromium-iron alloys of one group, which, on account of their somewhat lower strength, were examined at 650° C. In the majority of cases the usual short-time tensile tests were carried out at room temperature, 650° C. and 800° C. It is, however, realised that the order of merit of different materials is probably not the same at lower or higher temperatures as at 800° C. or 650° C.

THE NICKEL-CHROMIUM ALLOYS.

Under stable-equilibrium conditions in the nickel-chromium alloys at 800° C., a second constituent occurred in addition to the nickel-rich solid solution when the chromium content reached 40%. A corresponding fall in the values of the mechanical properties was found. The strength of the 40% chromium alloy, both at room temperature and at 800° C., was lower than that of the alloy containing 30%. The alloys containing 50% and 60% of chromium possessed poor mechanical properties.

The general results of the tests indicate that increased endurance as regards prolonged stress at 800° C. may be obtained by raising the chromium content beyond 20%. As far as the examination has been carried, the best properties were found in the 70/30 alloy. At a lower temperature—namely, 650° C.—alloys of lower chromium content showed better results. The 90/10 rolled alloy containing a small addition of carbon appeared to be stronger than the 80/20 alloy. At higher temperatures, such as 1,000° C., it is possible that alloys with somewhat higher chromium contents may be more suitable.

It was found difficult to prepare sound ingots of this series in sand moulds, but some preliminary tests indicate that sand-cast material is probably stronger than chill-cast.

THE NICKEL-CHROMIUM-IRON ALLOYS.

A systematic survey of the properties of the rolled nickel-chromium-iron series was carried out upon alloys containing 20 to 40% of chromium, both with and without additions of carbon. The majority of the nickel-chromium-iron alloys appeared to consist mainly of the nickel-austenitic-iron solid solution, and lay, therefore, outside the martensitic range, but a limited number of the iron-rich alloys were affected by the $\gamma - \alpha$ transformation. In these cases very high values for the properties of these alloys at room temperature occurred. This group of alloys appears suitable for use at temperatures such as 650° C., whereas for service at 800° C. the binary nickel-chromium group is probably preferable to the simple ternary nickel-chromium-iron alloys.

Whereas it was found that successful deoxidation of the molten metal before casting is a very important factor in the preparation of nickel-chromium alloys, it is probable that in the case of the ternary alloys containing iron the rate of pouring and the temperature of the molten metal before casting are also highly important. The chromium-iron alloys are relatively easy to prepare, but it is likely that the effect of nitrogen will be quite marked.

THE COMPLEX NICKEL-CHROMIUM-IRON ALLOYS.

Some of the complex nickel-chromium-iron casting alloys containing elements such as carbon, silicon, tungsten, titanium, or molybdenum, possessed markedly improved mechanical properties. These alloys were developed as the result of a series of experiments representing isolated points in a very wide field, the added elements having been selected on very general grounds regarding their probable effects. In view of the progress achieved by this tentative method, it is likely that considerable further advance in the production of alloys of still higher strength at high temperatures under prolonged loading is possible if a more extensive systematic investigation be undertaken. The maximum load under which the alloys did not flow appreciably was not determined owing to the lengthy nature of the tests involved, but comparison was made on the basis of the stress required to break the alloys after a long period of time under load.

An interesting deduction was made during the course of the work in relation to the ratio of the tensile strength at 800° C. to that determined at room temperature, as indicated by the usual short-time tensile tests. The most resistant alloys possessed in the "as-cast" condition a high ratio between these two figures. One alloy, for instance, exhibited a strength of 48.4 tons per sq. in. at atmospheric temperature, and a strength on short-time test as high as 30.6 tons per sq. in. at 800° C.

The alloying additions rendered the alloys considerably harder, and therefore less ductile, at high temperatures. In consequence, many of the resulting materials were too hard at the customary rolling or forging temperatures to be wrought successfully. In those cases, however, where the alloys were successfully rolled or forged, they were found to have a considerably greater life at 800° C. in the cast condition than similar material in the rolled condition under the same circumstances. The rolled materials showed, however, a relatively low ratio of tensile strength at 800° C. to that at room temperature.

Copper Chromium Structural Alloys.

By J. A. JONES, M.Sc.

IN a previous paper the author investigated the effect of carbon, manganese, silicon, and nickel on the properties of structural steels, and it was concluded that the type giving the best tensile properties was that containing 0·3% C, with about 1·3% Mn, and 0·9% Si. Further work has been carried out with a view to studying the effect of composition on the mechanical properties in the series of crucible steels containing 0·3% C and various amounts of manganese, chromium, and copper. The steels investigated contained about 0·3% C, 0·5 to 1% Mn, up to 1·5% Cr, and up to 1·2% Cu, while all contained less than 0·1% Si, 0·045% S, and 0·025% P. As a result of these investigations it was concluded that steels containing chromium in addition to manganese do not offer any advantage for structural purposes over the usual type of steel containing high manganese only.

The addition of from 0·5 to 1·2% of copper to steels containing up to 1% of chromium, leads to a marked improvement in the properties. In addition to their improved resistance to atmospheric corrosion, steels containing about 1% of copper offer the further advantage that they are less sensitive to variations in the rate of cooling after normalising.

Within the range of composition investigated, the best properties were obtained in a steel containing 0·3% of carbon, 0·5% of manganese, 0·9% of chromium, and 1·2% of copper. The mechanical properties of this steel compare favourably with those of the best manganese-silicon structural steels, and are better than those obtainable in structural steels containing high manganese only.

Carburising and Graphitising Reactions between Iron-Carbon Alloys, Carbon Monoxide and Carbon Dioxide.

By M. L. BECKER, B.Met., Ph.D.

THIS investigation has been carried out for the British Cast Iron Research Association, the object being to throw light upon some abnormalities in the behaviour of cast irons at elevated temperatures, as well as to suggest possible means for inhibiting growth, scaling, etc., of cast irons and steels. It was anticipated that the results might also be applied to the more accurate control of processes involving carburisation or decarburisation.

The author discusses the theory underlying the oxidation, carburisation, graphitisation of steels and irons in the presence of CO and CO_2, and describes a new method by which equilibria between the gases and carbon or steel may be studied. In this method, the partial pressure of CO_2 in the reacting gas is controlled by varying the temperature of a dissociating carbonate. By subtracting the known CO_2 tension from the measured total pressure, the CO tension is obtained. From these values the composition of the gas in equilibrium with carbon or steel may be deduced. The method has been used to determine the compositions of the gas in equilibrium with steels of varying carbon content, and the results for a number of temperatures have been plotted. Broadly speaking, the temperature composition diagram produced confirms that already published by Johansson and von Seth.

The composition of the gas in equilibrium with graphite has been found to vary over a range of temperature from 650° to 1,000° C., in accordance with determinations made by previous workers. Furthermore, the gas in equilibrium with iron carbide plus saturated solid solution, is found to be richer in CO than that in equilibrium with graphite at the same temperature. The carbon vapour pressure of iron carbide must, therefore, be higher than that of pure carbon, at any rate between 650° and 1,000° C. It would therefore appear that graphite is stable with respect to iron carbide over this range of temperature. This inference is not in accord with the views of Matsubara or Johansson and von Seth, who considered the carbon vapour pressure of carbide to be lower than that of graphite at temperatures above about 800° C.

The influence of silicon, manganese, nickel, and chromium upon the equilibria has also been investigated.

The Interaction of Gases and Ore in the Blast-Furnace.

By W. A. BONE, D.Sc., F.R.S.; L. REEVE, Ph.D.; and H. L. SAUNDERS, Ph.D.

IN the author's previous paper the principal investigations bearing on fuel economy, on the interactions between gases and ore, and on the factors and laws governing both reaction velocities and equilibria in the blast furnace were reviewed. This paper concerns the further exploration of carbon decomposition at temperatures below 550° C.; a comparison between the relative reducing powers of the so-deposited carbon and of carbonic oxide, upon oxides of iron at temperatures higher than 650° C.; the determination of the CO/CO_2 equilibrium ratio in systems containing Fe_xO_y, Fe, CO, and CO_2, and possibly also deposited carbon, at temperatures between 650° and 1,200° C.; and the ascertainment of the separate and combined influences of such factors as temperature, the "distance potential," of the gases from their resultant equilibrium point, and gas velocity upon the rates of ore reduction and carbon deposition respectively, at various selected temperatures. Owing to the complexity of the phenomena involved, which the authors have found greater than was supposed when the research was undertaken, the experimental difficulties can be overcome only after much investigation and the closest attention to details.

The results of these investigations indicate that the carbon deposition, due to the reversible reaction $2CO = C + CO_2$, begins at quite low temperatures (for instance, slowly at 275° C.), and its optimum temperature is about 450° C.; it is, however, a catalytic phenomenon, in the sense that it does not occur in the absence of a suitable catalysing surface. Iron, Fe_3O_4, and FeO are all powerful promoters of carbon deposition at temperatures up to between 650° and 700° C., and round about the optimum temperature there appears to be no limit to its progress. At higher temperatures, however, the phenomenon becomes inappreciable until nearly 90% of the possible ore reduction has been completed, when it again becomes prominent. Such carbon deposition in the blast-furnace at temperatures between 275° and 700° C. may result in either or both a *carbon-impregnation* and/or a *carbon-envelopment* of the ore granules, the former being beneficial to ore reduction, but the latter scarcely so.

The carbon deposited in the pores and interstices of carbon-impregnated ore granules is a much more powerful ore reducer than carbonic oxide at 750° C. Carbide formation (if any) seems always to be conditioned by the presence of free iron in a system containing both oxides of carbon and an ore undergoing reduction.

Determinations of CO/CO_2 equilibrium ratios in the systems $Fe_3O_4 + CO = 3FeO + CO_2$ and $FeO + CO = Fe + CO_2$ have been made at temperatures of 750°, 850°, and 975° C., with results very closely agreeing with those previously obtained by Matsubara.

Measurements have been made of the rate of approach to equilibrium over the 30 to 65% ore-reduction range using two ores, and they indicate that of the two, one ore is more readily reduced. The investigations further indicate that sintering occurs when charges of partially reduced ores are maintained for considerable periods at temperatures above 750° C.

A special apparatus has been devised to permit of the detailed study of relative reaction velocities between blast-furnace gases of any given composition and iron ores at all stages of reduction, at all temperatures up to 1,200° C., and provision has been made for the determination of the extent to which variations in the speed of gas flow over the

ore surface at rates comparable with those obtaining in the blast-furnace influences these reaction velocities.

Professor Bone, in his remarks when introducing this paper, expressed the need for more co-operation than had hitherto existed with blast-furnace people on the question of ascertaining data, not only as to the composition of gases, but data as to the material in the furnace at different temperatures, because until those data were obtained they were largely talking in the air as to the application to blast furnace practice of the scientific results obtained in the laboratory.

Mr. Fred Clements, chairman of the committee under which Professor Bone is carrying out his work, said that the paper could only be regarded as an interim report, and, in a subsequent discussion, called attention to a number of points on which a surprising amount of ignorance existed. Professor H. E. Armstrong, Mr. E. C. Evans, Mr. H. E. Wright, Mr. R. A. Hacking, and the President joined in the discussion.

The Corner Ghost in Steel Ingots.

By Dr.-Eng. SOJI MAITA (Japan).

GHOST marks are a particular form of ingot segregation that may occur as actual defects or only as markings in the metal. Corner ghosts come under this category, and are usually found at the corners of polygonal ingots, and may occur in round ones. Their principal cause is rapid cooling of the steel during the formation of the external crystal zone from the molten metal. This is due to the brittleness of steel at high temperatures, near to the solidification temperature. The mechanism of the formation of corner ghosts is referred to as follows :—

Rapid cooling gives rise to some deformation in the external crystal zone, and creates in it an internal loose structure or fissure, which is then filled up with fluid segregate ; such conditions may be accelerated by conditions inherent in the ingot body and its composition. Furthermore, some corner concentrated segregation may sometimes develop spontaneously.

The Effect of Melting Conditions on the Microstructure and Mechanical Strengths of Grey Cast Irons containing Various Amounts of Carbon and Silicon.

By A. L. NORBURY, D.Sc., and E. MORGAN, M.Sc.

THIS paper is divided into two sections. The first is a continuation of a previous paper, entitled, " Constitutional Diagrams of Cast Irons and Quenched Steels," and contains the results of some experiments on the effect of melting conditions, such as superheating, additions of steel, silicides, graphite, gases, and iron oxide on the microstructure and mechanical strength of grey cast irons.

In these experiments the refining action of superheating on the graphite structure was confirmed, and it was also found that steel additions act in a similar manner, additions of 1 or 2% of steel having a remarkable action on the graphite. Additions of 40% ferro-silicon, on the contrary, were found to have a coarsening action on the graphite, the irons produced having pearlitic matrices and high mechanical properties if of suitable total carbon and silicon contents. Additions of 10% ferro-silicon, 60% calcium silicide, and 5% nickel silicide were made to ladles of cupola metal which would have solidified white without such additions ; the resulting test-bars were grey, and had good mechanical properties. 10% ferro-silicon (melting point, 1,200° C.) and nickel silicide (melting point, 1,280° C.) alloy readily ; 40% ferro-silicon, with a melting point of 1,400° C., alloys less readily, and calcium silicide still less readily. Bubbling nitrogen through crucible melts was found to have no appreciable effect. Similarly, with hydrogen, and hydrogen and nitrogen simultaneously, the passage of the gas appeared to improve the mechanical properties, if anything, by removing slag from the melt. On adding iron oxide scale to a melt which had been saturated with hydrogen, a brisk evolution of gas occurred, as if the oxide were combining with hydrogen to form steam. Bubbling carbon dioxide through the melt caused the formation of considerable quantities of finely divided slag, probably a silicate. Additions of iron oxide to the melt produced a frothy slag, incandescence, and thickening of the melt ; they also caused the removal of manganese, silicon, and carbon by oxidation. The amount of each removed when expressed as a percentage of the amount of each present was greatest for manganese, less for silicon, and least for carbon. The resulting test-bars of oxidised metal were not appreciably lower in strength, but under the conditions of the experiments the products of oxidation were removed from the melt.

The second part of this paper gives the results of tensile, transverse, repeated impact, Brinell, drill-hardness, and specific gravity tests carried out on a number of grey cast irons having total carbon contents between 1·5 and 4·0% and silicon contents between 0·5 and 10%. Some of the irons were made in such a way that they contained both " normal " and " super-cooled " graphite ; they had relatively low mechanical strengths. Others contained only " super-cooled " graphite. The remainder, which were melted in a different manner, contained only " normal" graphite.

The results of the tests show that the mechanical strengths and hardness of the grey irons tested are dependent on their analyses and microstructures. In pearlitic irons the strength and hardness increase as the total carbon decreases, and as the distance below the eutectic composition increases. Areas of super-cooled graphite associated with ferrite in otherwise pearlitic irons cause a considerable lowering of the strength and hardness. In ferritic irons the strength and hardness increase as the distance below the eutectic increases and as the size of the graphite flakes decreases. In ferritic irons the strength decreases, but the hardness increases as the silicon content increases.

Tin- and Sheet-Mill Rolls : Their Treatment, Performance, and Premature Failure in Service.

By E. R. MORT, B.Sc.

THE data in this paper relate to a sheet plant comprising sixteen hot mills of the single-stand type, all bars being broken down and finished off on one pair of rolls. Gauges of sheets rolled range from 6 B.G. to 31 B.G. inclusive, in width up to 50 in., and lengths up to 144 in. On twelve mills the body diameter is 32 in. and 28 in. on the remaining four. Body lengths range from 38 in. to 56 in. in conformity with the width of sheets in demand. The data refer to a period of two years during which time plant operations approached 100% of capacity.

Rolls for use in tin and sheet mills are almost invariably made of cast iron, bearing a chilled skin approximately $\frac{3}{4}$ in. deep, and when cast they are dressed. Many factors must be considered regarding the contours to which the bodies are dressed, and when finally placed ready for commission great care must be exercised in bringing the roll to the working temperature for the first time.

One of two methods may be adopted, by rolling hot packs or by electricity, steam, oil or gas flame. In this paper a description is given of the equipment for heating roll by fuel oil.

In dealing with roll performance calculated on a basis of tons of sheets per ton of roll, a wide range of results are shown which indicates the variation in the life of rolls supplied by several makers. Premature failure of rolls in service is considered, and causes of premature failure are dealt with under various headings, such as breakage, cracked body, spalling, shot-holes, mottle, and chill fracture.

The discussion was opened by Mr. G. H. Strick, who stated he had rather more silicon in the pig iron he employed than was to be found in the average analysis given in the

paper. Instead of 0·75% he generally used from 1 to 1·25%, and this satisfied the roll manufacturers when he was producing iron rolls. Mr. A. Allison in the course of his remarks said that this paper had done something towards clearing the air and smoothing over the differences of opinion which existed between the roll maker and the roll user. Mr. D. F. Campbell, Mr. J. Shaw, and Mr. H. S. Carnegie also joined in the discussion.

Single-Sheet or Thin-Back Normalising, or Heat-Treatment versus Box Annealing of Sheets.

By R. WHITFIELD.

THE phenomenal development of the motor-car industry has given rise to a demand for sheets having deep-drawing possibilities, and box-annealing has generally failed to produce such sheets by normal operations. A few years ago car bodies were designed on a series of straight lines, and the forms were produced by expensive jointing. By the use of normalised instead of annealed sheet, this has largely been eliminated, and now very large sheets are heat-treated and stamped to intricate shapes, producing the present graceful lines. It is with this normalising that the present paper is concerned.

The mass production of high-class sheets has received careful metallurgical examination, and practical means have been devised for achieving the improved results known to be obtainable. Annealing in a box-furnace offered only a partial solution, leaving the most important demands unsatisfied; practical difficulties prevented the attainment of the desired metallurgical results.

Modern artistic designs demand a high-quality sheet, having deep-drawing possibilities; the normalised or sorbitic sheet fulfils all the requirements. The solution of the problem lies in single-sheet or thin-pack heat-treatment, consisting of a careful preheating, soaking, and cooling—all controllable factors, unobtainable in a box-furnace. This method enables the necessary temperature to be easily reached and controlled, and by reason of the quick cooling the fine structure and physical results are maintained uniformly across the sheet.

The modern normalising furnace is a practical machine, very adaptable for the production of sheets to any specification, especially where box-annealing has failed. There are numerous advantages, apart from the superior metallurgical results, and there are undoubtedly possibilities for this process in other branches of the sheet trade.

Professor C. H. Desch opened the discussion, and in the course of his remarks stated that, seeing that the normalising process appeared to be so greatly superior to box-annealing, it should become generally adopted. If electrical heating were employed, it would be possible to regulate the process in such a way that the sheets on coming out of the furnace would be quite bright and unoxidised. Mr. A. T. Kathner and Mr. J. Fallon joined in the discussion, and Mr. Whitfield replied to points which had been discussed.

The Constitution of the Alloys of Iron and Silicon.

By J. L. HAUGHTON, D.Sc., F.Inst.P., and M. L. BECKER, Ph.D., B.Met.

THIS is the ninth paper embodying results of the research on the alloys of iron which is in progress at the National Physical Laboratory under the auspices of the Alloys of Iron Research Committee, and under the direction of Dr. Rosenhain.

The constitution of the alloys of iron and silicon have been studied by many investigators, but in spite of this large areas on the diagram either remain incompletely determined or show wide divergences between the results of different workers. It seems probable that these differences, which in some cases involve divergences in temperature data amounting to over 150° C., are in a large measure due to impurities in the materials used.

As a result of these further investigations, the constitution of the alloys of iron and silicon have been determined, using materials of a much greater purity than have been available before, and taking every precaution to avoid contamination of the alloys. Very considerable differences exist between the present results and those of the previous observers—differences which are doubtless due in part to the purity of the materials used. The existence of phases which appear to correspond with the compounds FeSi and Fe_3Si_2 has been confirmed, and in addition a phase which is probably the compound Fe_2Si_5 has been shown to exist.

Developments in Fuel Economy at Skinningrove.

By FRANK BAINBRIDGE.

As a result of investigations, the late Mr. T. C. Hutchinson predicted that with a proper arrangement and concentration of producing units, the time would come when ironstone would be brought in at one end of the works and finished steel would pass out at the other, only such coal being used as would be required for the coke-ovens to supply sufficient coke to smelt the ironstone. He also expressed the hope that he would live to see his prediction fulfilled at Skinningrove. The concentration of the productive plant has been achieved, but the application of the surplus gases was not sufficiently complete at the time of his decease to obtain the desired economies, and the Skinningrove plant lacked that balance considered essential if modern British blast-furnace and steel plant practice was to compete favourably with Continental practice. This paper deals with the factors involved in securing the desired economies, and while no claim is made at Skinningrove for any special novelty in the use of cleaned blast-furnace and coke-oven gas, nor in the methods of use, it is believed that the lines on which the management have worked to obtain extra benefits will be of interest. The methods adopted represent an attempt to bring into balance the outputs of the various producing departments, and in so doing to make available greater quantities of surplus gas by the installation of automatic burners on stoves and boilers, the further quantities so liberated being made use of in the production of steel.

Economies have also been achieved by the application of coke-oven gas to the open-hearth furnaces through water-cooled ports or burners.

Supplies of cleaned blast-furnace and coke-oven gases have been utilised by mixing them direct with the producer gas, this being made possible by the careful control and measurement of the volume and by the installation of simple diaphragm-type meters, and electrical regulators.

Mr. W. J. Brooke opened the discussion, and in the course of his remarks said he had come to the conclusion that the system proposed in the paper was not by any means the best, and he believed better results would be obtained by passing the blast-furnace and coke-oven gas together through the regenerator, as that course resulted in a reduction of the time necessary in the steel furnace, thus bringing down the cost very considerably. Professor Bone, who joined in the discussion, wondered if people dealing with blast-furnace gas were really applying the work that had been done in many laboratories on carbonic oxide and combustion. Mr. J. Henderson, Mr. T. M. Pervice, Mr. B. Talbot, Mr. D. Sillars, Dr. Stottman, and the President also joined in the discussion.

The Metallurgy of Some Ancient Egyptian Implements.

By Sir H. C. H. CARPENTER, F.R.S., and J. M. ROBERTSON, D.Sc.

THIS paper gives an account of the results of an examination of nine representative specimens of metal from the Egyptian collection of Sir Flinders Petrie. These were examined, not only from the point of view of their inner

crystal structure, but from what may be called their "micro-hardness."

The facts disclosed in this work indicate that carburising, quenching, and the advantages of heat-treatment generally, were understood many centuries before the Christian era. It has often been suggested that such operations were performed, but there has been no evidence. Hadfield, for instance, stated: "It is far more probable that the Ancient Egyptians were not only able to make steel for tools of all kinds, but also to cement and harden it." He considered, however, that this steel would be made by carburising direct iron. This suggestion, however, was based on the existence of the hard stone carvings, for the specimens examined by him were not of Egyptian origin, and belonged to a period some thousands of years later than that in which the hard stone carvings were first made.

In the opinion of the authors, it seems probable that the Iron Age did not properly begin in Egypt until the technique of carburising and heat-treatment generally had been discovered and well developed, or, to put the matter somewhat differently, it was not until iron had been converted into steels that the Egyptians obtained a range of alloys which were superior in their properties to bronze and capable of more varied applications. In countries, however, where bronze was practically unknown, where notable skill in its manipulation had not been attained, or where the requisite ores were not readily available, the investigation of iron would follow more closely on the first discovery of this metal, and its development and use would be more rapid.

The Properties of Some Steels Containing Chromium.

By A. R. PAGE and J. H. PARTRIDGE, Ph.D.

THE experiments described in this paper were originally designed to determine certain properties of steels which might be suitable for the exhaust valves of air-cooled internal-combustion engines. In the opinion of the authors, the most important properties of such steels are good mechanical strength combined with toughness at ordinary and elevated temperatures, and resistance to oxidation or scaling at temperatures to which an exhaust valve may be heated under bad engine conditions, and which may occasionally reach 800° to 900° C. A series of materials, all containing chromium, have been used, in which these properties have been determined, which have been divided into four classes—viz., plain chromium, silicon-chromium, nickel-chromium, and cobalt-chromium steels.

The results of the mechanical tests, after hardening, of two plain chromium steels are given, which indicate that one steel, air-hardened at 900° C., is brittle, whereas another steel, which contains a little more silicon, is not; further, the latter steel is apparently tougher and slightly more ductile, than the former, though not so strong.

Tests with silicon-chromium steels show that they are not very strong at temperatures in excess of 700° C. Silicon decreases the hardening properties; an increase of this element to 3½% makes the steel more brittle in the cold, and decreases the strength at elevated temperatures. A suitably heat-treated steel, containing 8% of chromium with 3½% of silicon, is stronger and more ductile at room temperatures than one with less chromium or silicon, but it is weaker at elevated temperatures.

The nickel-chromium austenitic steels apparently possess better static properties at elevated temperatures than the silicon steels. They are stronger and do not appear to be so plastic when hot. From the results obtained it would appear that there is little to be gained by increasing the nickel and chromium content from 9% to 12 or 13%. Further, it is indicated that the elongation and reduction of area of the nickel-chromium steels at various temperatures are fairly constant, whereas in the case of the silicon-chromium steels the values of these particular properties increase with increasing temperatures of testing. This is very evident at 800° C.; the nickel-chromium steel has a reasonable reduction of area, whereas the silicon-chromium steel pulls out almost to a point.

Only one high carbon steel containing approximately 12% of chromium and 3% of cobalt was made, but the results indicated brittleness on account of the high carbon content.

The History of the Cementation Process of Steel Manufacture.

By DAVID BROWNLIE and BARON DE LAVELEYE.

THE authors have collaborated in the search for authentic information respecting the history of the cementation process of steel manufacture. The paper is divided into two parts, one giving the results of a search of the Record Office, London, amongst the State and Domestic Papers of the reign of James I., while the second refers to an investigation made in some of the European countries. Original documents in Liége prove that Pierre du Coudraye and Jan van Buel made steel out of iron before January 19, 1613; it is quite true that cementation seems to have been the process for making steel out of iron about this time, and it is universally recognised also that the Liége Principality was one of the countries where iron and steel making were one of the principal industrial activities. But these facts point only to probabilities, and are not actual proofs regarding the invention of cementation. We certainly know no more now than we did before by which process the two inventors turned iron into steel, neither do we know for a fact that that process was a success and was regularly worked. The authors have, therefore, come to the conclusion that the invention of the cementation process and the manufacture of steel remains as much a mystery as ever.

U.S.A. Iron and Steel Exposition.

THE Iron and Steel Exposition and Convention to be held at Buffalo, N.Y., during the week of June 16 has been announced. Over 50,000 sq. ft. of surface will be occupied by the display of equipment, devices, and processes.

Tentatively, the technical programme to be covered will be as follows:—

Electric welding and heating. Standardisation of electric overhead travelling cranes.

Standards in connection with use of anti-friction bearings on general purpose motors and electric overhead travelling cranes. Plasticity of steel. General description of most modern steel plants. Developments in rolling-mill practices. Electric developments in iron and steel industry. Use of portable electric tools for production and maintenance work in the iron and steel industry. Illumination and its problems in iron and steel industry. Gas utilisation in iron and steel industry. Gas producers in iron and steel industry. Steam generation and its utilisation in iron and steel industry.

Use of liquid fuels in iron and steel industry. Mechanical and electrical maintenance shop practice. The use of air and gas-conditioning apparatus for iron and steel industry. Topical discussion: Problems in furnace installation, operation and maintenance in iron and steel industry. Use of instruments and control in furnace practice in iron and steel industry. Should universities and colleges create a safety engineering course?

The papers and discussions will represent the latest developments in each phase of the industry.

Some Metallurgical Problems Connected With the Possible Use of Very High Steam Temperatures.

By J. H. G. MONYPENNY, F.INST.P.

IN a paper entitled "The Limiting Possibilities in Steam Plants," and read before the North-East Coast Institute of Engineers and Shipbuilders on February 27, 1925, Professors Mellanby and Kerr stated that temperature limits were strictly and entirely a problem of materials. "Thermodynamically there is no limit to the upper temperature that may be used, but the weakness and deterioration of metals under high temperature conditions must introduce a real limit. Hence, the evidence regarding temperature limits must be sought in the properties of metals." At that time the question of creep or flow of metals at high temperatures had been but lately discussed. Much research has been carried out in the five years that have since elapsed, but the problem remains much the same. The investigations have served

Fig. 1.—5% *Nickel Steel Turbine Blading, after three years' service.*

largely to indicate the very real limit which the employment of ordinary carbon steels places on steam temperatures, and the equally real difficulties which are encountered when attempts are made to increase this limiting temperature by the use of special alloys.

During past years steam temperatures in connection with large power plants gradually crept up to 750° F., where they remained practically stationary for some time. The last few years, however, have seen a definite tendency for the use of higher temperatures—800° F., 850° F., 900° F., while 950° F. and 1000° F. are suggested. While the working temperature did not exceed about 750° F., ordinary carbon steels gave satisfactory service, except for special parts, but at still higher temperatures they may fail to give efficient service for at least three reasons; their strength at such temperatures is inadequate, and they are not sufficiently resistant to corrosion and erosion while so heated. Of these three shortcomings the first is by far the most serious.

Corrosion has not usually been regarded as a serious difficulty in the past; it was certainly important, but its effects in steam plant could be lessened by greater care in the elimination of occluded gases and impurities in the boiler feed water. While this was true as regards boiler, superheater, and general construction, corrosion troubles were not altogether unknown; thus they have had at times pronounced effects on the efficiency of turbine blading, as is evident from the blades illustrated in Fig. 1. These were made of 5% nickel steel, and had only been in use for about three years. The possibility of eliminating this undesirable condition by the use of stainless steel, in one form or another, has now been very generally recognised, and there is no reason, except the doubtful one of economy on first cost, for the use of blades which will lose their efficiency so rapidly as those illustrated in Fig. 1.

Corrosion troubles may not be greatly intensified by raising steam temperatures from 750° F. up to about 900° F., but above this temperature a new difficulty arises. When steam and mild steel are in contact above about 900° F., they react on one another, producing hydrogen and iron oxide. This reaction attains appreciable magnitude at about 900° F., and is very distinct at still higher temperatures. Both its products are undesirable, and hence it puts an upper limit to the use of ordinary carbon steel in superheaters, for example.

The incidence of this reaction can, however, be delayed until considerably higher temperatures than 900° F. by the use of high-chromium steels. A series of experiments were carried out some time ago at Brown, Bayley's Steel Works, Ltd., in which superheated steam was passed through tubes of mild steel, of stainless iron, and of "Anka" steel (an austenitic chromium-nickel steel containing 15/16% chromium and 10/11% nickel), which were maintained at a temperature of 1000/1050° F. The mild steel tube was rapidly attacked, about half a litre of hydrogen being collected during the first four hours of the experiment. On the other hand the stainless iron and the "Anka" steel were tested for 223 and 1176 hours respectively, and in neither case was hydrogen given off, nor was there any visible attack produced on these tubes.

The writer understands that experiments carried out in the United States of America, on similar lines to these, indicate that attack on the high-chromium material does not become appreciable until temperatures of 1200/1250° F. are reached.

Erosion troubles due to high superheats are not regarded as insurmountable. They are presumably to be looked for in the first few rows of blading in the high-pressure stage of a turbine using very highly heated steam. There seems no reason, however, why the ordinary stainless irons and steels, which have proved so successful in turbine construction during the last few years, should not retain their effectiveness to still higher temperatures than those for which they already have been used; but if it were found that something stronger and more able to resist erosion at these high temperatures was necessary, the cost of the turbine would not thereby be very greatly increased even if, as is very likely, the substituted metal was much more expensive, because the trouble would be confined to the first few rows of blades, and the latter in this position are relatively small and not of great number, and hence would not involve the use of a large weight of material.

It seems possible, however, that the erosion encountered in this part of a turbine may not be so serious as that already found at the low pressure end, and due to the impingement of drops of condensed water on the backs of the leading edges of the blades.

The resistance of steel against prolonged loading at high temperatures has attracted a great deal of attention during the last four or five years, and, as a result, a considerable mass of data has been accumulated by various workers. Possibly the most noticeable feature of these data, when one attempts to compare the results obtained on similar materials by different workers, is their variableness. For example, the curves in Fig. 2 all relate to ordinary mild steel, containing 0·2/0·24% carbon, and represent the values given by different investigators for the stresses with which this material may be safely loaded for long periods at the temperatures indicated.

Actually, this variableness is not really surprising. The determination of a "limiting creep stress" (if such a thing really exists at temperatures of 400° C. and upwards) depends ultimately on the sensitiveness and accuracy of the means available for measuring the constancy in length of a given sample while heated at these temperatures. If a number of test pieces of a given steel are loaded to different amounts at some given temperature, and the relation between extension and time determined in each case over a considerable period, the curves representing this relation will be of one or other of two classes, depending on whether the temperature in question is above or below that at which the metal ceases to strain harden. In the latter case, the metal being capable of strain hardening, the initial elongation (produced if the stress is sufficiently high to cause plastic extension) is followed by a period in which the rate of stretch gradually becomes less, until it reaches some constant value characteristic of the particular load. This steady rate of creep is slower, the lower the stress, and, as the latter is reduced, is assumed to become zero at some given load representing the "limiting creep stress;" see Fig. 3. At temperatures above that at which the metal is capable of strain hardening, it is difficult to see how a rate of creep set up in the metal can ever become zero, though, owing to viscosity, it may possess an exceedingly small value. On this basis, therefore, relation between extension and time for various loads at these temperatures should be as indicated in Fig. 4.[1]

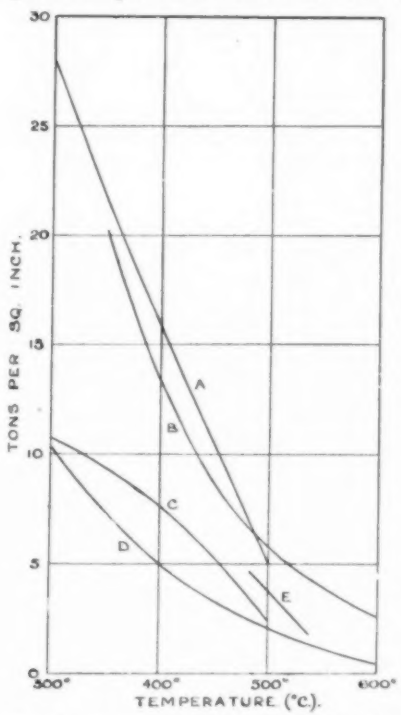


Fig. 2.—Creep Stress Values for Mild Steel, 0·2/0·24% Carbon.

A. Tapsell and Clenshaw.
B. Cournot and Sasawaga.
C. Pomp and Dahmen.
D. French, Cross and Petersen.
E. Norton.

Two interesting problems arise here: do the curves in Fig. 3 become horizontal when the stress is lowered to some definite value—*i.e.*, is there such a thing as a "limiting creep stress,"—and at what temperature does a metal begin to recrystallise after strain hardening? It is understood, of course, that recrystallisation, even if only partial, removes to a greater or less extent strain hardening.

The first problem can only be solved within the limits of accuracy with which constancy of length can be determined. This subject has been discussed in some detail by Dr. Hatfield,[2] who has pointed out the difficulties in experimental work. It is probable that in few, if any, published creep-stress values has the rate of extension

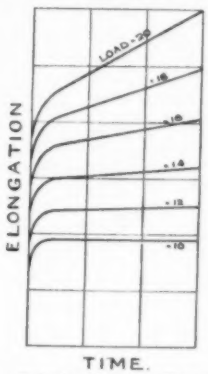


Fig. 3.—Relation between Elongation and Time, metal strain hardens.

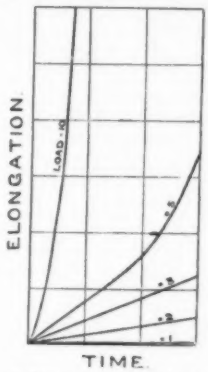


Fig. 4.—Relation between Elongation and Time, metal does not strain harden.

of the various test pieces been determined to a smaller value than one millionth of an inch per inch per hour, and many determinations do not reach this degree of accuracy; it may not be amiss, therefore, to mention that at this rate of creep a bar 12 in. long would extend 0·105 in. in a year. Whether such an extension would be serious or not, from a practical standpoint, would depend on circumstances, but it has been stated that there are parts, *e.g.*, in turbine construction, where a rate of creep of 10^{-8} per hour is important. To determine such a rate, the sensitiveness of the apparatus used for published data on creep stresses would need to be increased at least a hundredfold.

It may be pointed out, however, that if available data on the relationship between creep rate and stress be plotted logarithmically, a practically straight line is produced with no suggestion of a creep limit. This was shown by R. W. Bailey[3] for the results obtained on Armco iron at the National Physical Laboratory, and more recently by Norton[4] on an extensive range of steels. In Fig. 5, for example, are plotted the data on Armco extracted by Bailey from the N.P.L. curves, and they afford little evidence that, at any of the temperatures under test, the rate of creep becomes zero at some given stress. On the other hand, they do suggest that the

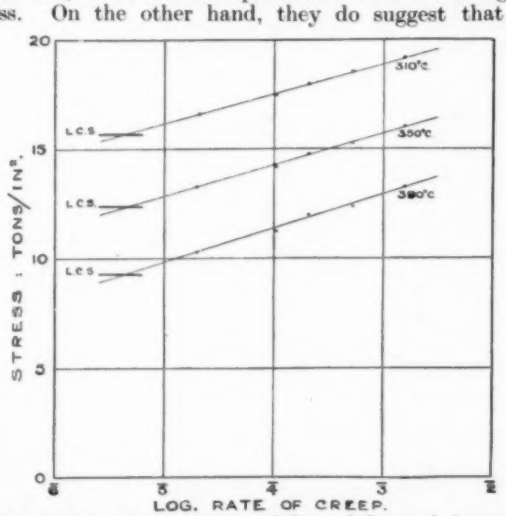


Fig. 5.—Relation between Stress and Rate of Creep of Armco Iron at Various Temperatures. (N.P.L. data; L.C.S. = Limiting Creep Stress).

sensitiveness of the apparatus did not permit a rate of creep of less than about $10^{-5.4}$ per hour to be measured.

The second problem has an important bearing on the influence of time on the creep-stress values. Cold-worked

iron, for example, loses the greater part of its acquired hardness by a short reheating to about 570° C.; also its previously distorted crystals are at the same time replaced by others, equiaxed and undistorted. Chapell[5] showed, however, that the initial stages of recrystallisation could

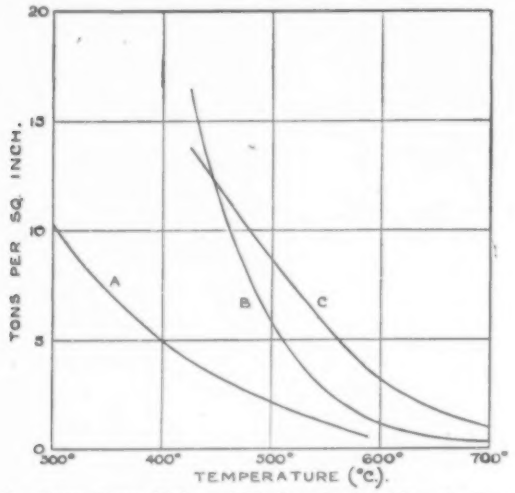


Fig. 8.—Creep Stress Values of Various Steels. (French, Cross and Petersen.)

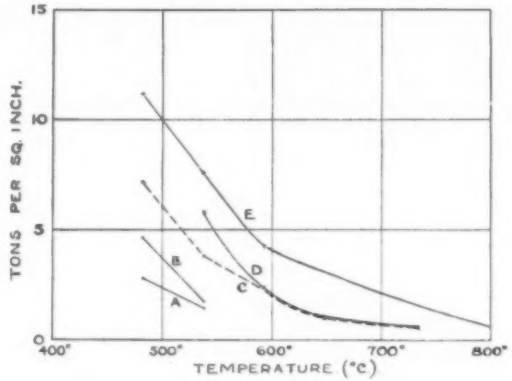
	C.		Cr.		Ni.		Cu.
A.	0·24	..	—	..	—	..	—
B.	0·28	..	20·5	..	—	..	0·98
C.	0·24	..	18·1	..	23·3	..	—

Fig. 9.—Creep Stress Values of Various Steels. (Norton.)

	C.		Cr.		Ni.
A.	0·08	..	—	..	—
B.	0·20	..	—	..	—
C.	0·10	..	17·6	..	—
D.	0·11	..	13·2	..	—
E.	0·09	..	18·1	..	8·1

be detected microscopically after a cold-worked sample had had a short reheating at 350° C. How much further would this have advanced on prolonged exposure to this temperature, and what effect would such a heating have on the hardness of a sample so treated? If the effects of cold work are removable, even partially, by prolonged heating at these temperatures, the strain hardening of a sample produced by any initial extension is likely to be gradually removed and hence lead to further creep. The line of thought thus started extends far; for example, are structural changes to be looked for in steels in general, even when not previously cold worked, by long-continued heating at high steam temperatures? Some interesting observations on this point have recently been made by R. W. Bailey,[6] who, on examining a superheater tube which had been in use for 16,000 hours, found that spheroidisation of the carbide of the pearlite had occurred near the outlet end of the tube, where the temperature had probably been about 450° C. Experiments carried out on samples cut from the inlet end of the tube (where the working temperature had been lower and had produced no obvious structural change) showed that at temperatures between 600° and 700° C., the relationship between absolute temperature and time taken to produce spheroidisation followed an exponential law, and that extrapolation of the curve obtained to the ordinate representing the life of the condenser tube gave a temperature value in the range 400°/475° C.

These results suggest that structural changes of a like nature may be expected in other steels, and as the balling-up of cementite—whether existing previously as the lamellæ of pearlite or as the fine globules of sorbite produced by hardening and tempering—will tend to diminish the strength of the steel in which it occurs, it may be suggested that the results of creep tests obtained in a relatively short time (*e.g.*, in a week or two), no matter how accurately carried out, are likely to give higher values for creep stresses than those occupying a much longer time; unless, of course, the samples tested possessed, owing to prior treatment, a structure unlikely to be affected appreciably



by long-continued heating at the temperature under test.

It seems probable, therefore, that the engineer will have to be content with "creep-stress" values which have reference to certain definite rates of creep, and from which he will have to try and estimate the useful life of his high temperature equipment. Obviously, the permissible amount of "creep" will vary in different parts of that equipment. And equally obviously, experimenters who investigate creep-rate values should state to what rate of creep their data have reference, otherwise the latter's value as a basis for design is limited. The accumulation of such data takes time, and probably the engineer will have to make use of such figures as are extant. From this point of view, however, there is a considerable amount of practical experience among engineers as to the behaviour of mild steel at 750° F. (399° C.), and such information may usefully be coupled up with the available comparative data obtained by creep-stress methods on mild steel and other steels at this and higher temperatures. Incidentally, it may be noted that if the published data for limiting creep-stress values be examined in this light, much better

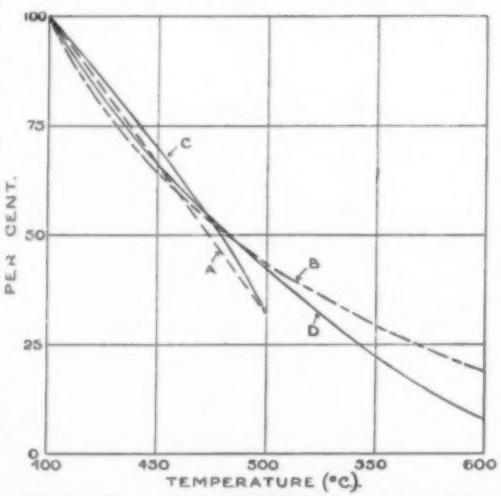


Fig. 6.—Creep Stress of Mild Steel at 450°/600° C. expressed as a Percentage of its Value at 400° C.

A. Tapsell and Clenshaw.
B. Cournot and Sasawaga.
C. Pomp and Dahmen.
D. French, Cross and Petersen.

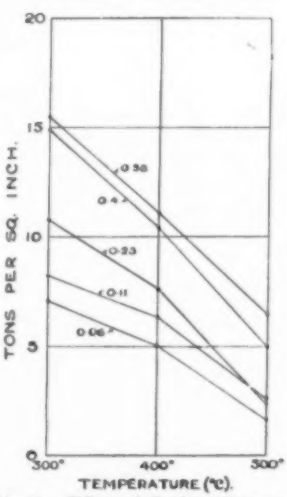


Fig. 7.—Effect of Carbon Content on Creep Stress of Steel. (Pomp and Dahmen).

agreement is found between the results of different investigators. For example, Fig. 6 gives four sets of creep-stress values obtained for mild steel in the range 450°/600° C., plotted as percentages of the values given by the same investigators for 400° C. It is obvious that these curves show much better agreement than do those, A—D in Fig. 2, on which they are based.[7]

An inspection of the curves in Figs. 2 and 6 brings out two facts very strongly. In the first place, at a temperature of 450° C. (842° F.) the least optimistic estimate for the safe strength of mild steel is about three tons per square inch. Secondly, the safe stress falls so rapidly with rise in temperature that an increase of 10° C. lowers this stress about 10%. It is thus obvious that either a very considerable factor of safety must be used to cover possible or probable temperature fluctuations, in addition to the uncertainties ordinarily covered by this factor—in which case the stress to which mild steel may safely be submitted at these temperatures is exceedingly low,—or it must be arranged with certainty that all temperature fluctuations shall be below, and not above, that selected for determining the creep-stress value to be used as a basis for design.

An examination of data obtained by various observers indicates that the creep strength of steel is raised by increasing, within limits, the carbon content, or by adding certain alloying elements. Fig. 7, for example, gives data obtained by Pomp and Dahmen[8] on various carbon steels, while Figs. 8 and 9 summarise the results of French, Cross and Petersen[9] and of Norton[10] on some alloy steels; the marked increase in strength in both directions mentioned above will be noted. At the same time it is equally evident that the highest creep strength obtained by these investigators is 10 tons per sq. in. at 500° C., and 4 tons per sq. in. at 600° C., values much lower than the tensile strengths at atmospheric temperatures with which the engineer is accustomed to deal.

Having thus discussed the problem of strength on general lines, it is proposed, in a succeeding article, to note the special difficulties which are likely to arise in some particular parts of high-temperature steam equipment.

(To be continued.)

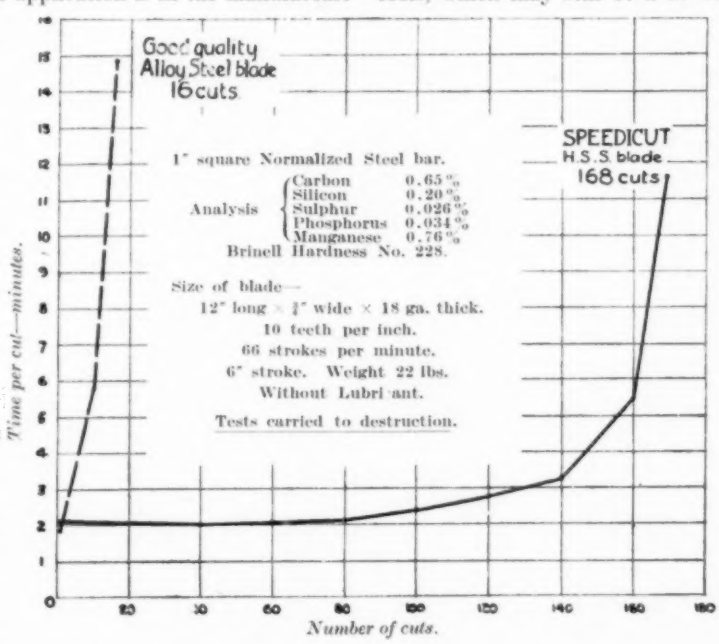
1 Figs. 3 and 4 are based on diagrams given by French, Cross and Petersen. Bureau of Standards Tech. Paper No. 362.
2 "Metallurgist" (Supplement to "Engineer"), 1929, pp. 108 and 117.
3 "Engineer," May 3, 1929, p. 488.
4 "Creep of Steel at High Temperatures," F. H. Norton; McGraw-Hill Pub. Co., 1929.
5 "J.I.S.I." 1914, I. 460.
6 "Engineering," February 21, 1930, p. 265.
7 This convenient method of plotting creep stress values was first suggested to the writer by Mr. R. W. Bailey.
8 Stahl and Eisen, 1927. I. 414.
9 Bureau of Standards Tech. Paper No. 362.
10 "Creep of Steel at High Temperatures."

High-Speed Steel Hacksaws

By J. H. Barber, M.I.Mech.E.

ALTHOUGH high-speed steel has been in general use for turning and planing, etc., tools and drills for some 25 years, it is only comparatively recently that its application has been extended to certain rather obvious subsidiary operations—reamers and lathe centres are cases in point. Perhaps the most recent application is in the manufacture of hacksaw blades. The high-speed steel hacksaw blade had its origin in Sheffield some four or five years ago, and now has to a considerable extent displaced, for machine use, the so-called alloy steel blades containing 1% to 2% of tungsten, which up to that time had held the field.

When the high-speed steel blade was first introduced considerable doubt existed in the minds of users as to the feasibility of employing a material hitherto regarded as comparatively brittle—at any rate, less susceptible to the niceties of tempering. Practice has proved that this fear was groundless.



As compared with ordinary alloy steel blades the performances of high-speed blades are remarkable, but it is only recently that the capacity of these blades has been translated into a proper relation to output. The reason may be found in the fact that machine-makers have only quite recently evolved machines capable of meeting the new conditions, and, in the writer's opinion, finality has by no means been reached in this direction. Without suitably speeded machines the capacity of the high-speed blade was mainly in its ability to cut harder material and maintain a life of from five to ten times that of the alloy steel blade when working under the same conditions. Coming now to actual performances, the following comparison of results obtained with a well-known brand of high-speed steel hacksaw blades, and a very good brand of alloy steel blade will indicate the possibilities in these tools, which may still be a novelty to many people.

It is not generally appreciated that sufficient heat may be generated at the cutting points to draw the temper of a carbon steel hacksaw blade and seriously affect its cutting property, even when running at the orthodox rate of 60 strokes per minute without coolant. It is this characteristic which limits cutting speeds, and it is probable that the majority of hand-operated blades fail through over-speeding.

High-speed steel, containing 14% tungsten or more, and hardened at 1,300° C., retains its hardness at temperatures somewhat exceeding 600° C. (a dull red heat), and it is this property which has caused it to take the place of cast steel in those operations where the influence of cutting may be to generate heat.

Even more recent is the use of hand blades in high-speed steel, and although a little more care against breakage may be required it is more than offset by the resistance of the teeth to destruction by too rapid manipulation. An alloy steel hand blade should be used at a speed not exceeding 60 strokes per minute, whereas a high-speed steel hand blade would not suffer at any speed at which it would be likely to be used.

The Influence of Technique on Research.

The twentieth May lecture to the Institute of Metals was delivered on May 7 by Major F. A. Freeth, O.B.E., D.Sc., Ph.D., F.R.S., from which the following has been extracted:—

The influence of technique on research is a subject of the greatest importance to science, discovery, and industry, for science and discovery advance by research and industry is in the long run dependent on the first two. One of the most obvious and important of maxims which has been a means of stimulating discovery is a proper control of the variables of nature, and the possibility of manipulating matter and subjecting it to treatment under the most varied conditions. This is what the lecturer means by technique. He referred to one or two of the great schools of discovery which have owed a great deal of their success to difficult methods of manipulation. The discovery of the rare gases of the atmosphere by the late Sir William Ramsay is a classic instance. That discovery originated from discrepancies in a physical constant of nitrogen prepared chemically from nitrogen derived from the atmosphere. It was Ramsay's extraordinary powers of manipulation, however, the originality of his technique, which clinched discovery and made success possible. The famous low-temperature school of the late Professor Kamerlingh Onnes, of the University of Leiden, was referred to as notable for the discovery of supraconductivity. In more recent times the wonderful experiments in the high magnetic field by Kapitza—largely the result of technique—will undoubtedly give results of the greatest theoretical importance. Major Freeth also mentioned the wireless valve that has been evolved from a vacuum technique.

Turning to industry, reference was made to the remarkable results achieved by the chemical technologist during the past decade by his new pressure technique. The lecturer stated he was convinced that the study of metals is as yet almost in its infancy, in spite of the voluminous and magnificent work which has been hitherto accomplished. Metallurgical progress will depend upon the way in which the difficult conditions, inseparable from this work, can be manipulated. In a further reference to the importance of technique to those engaged in the study of metals, mention was made of microscopy and the induction furnace, with their elaborate technique, and with which discovery is advanced at a much greater rate than would be possible otherwise.

The question of what might be done, given existing resources and technique, in the way of immediate discovery is a fascinating one. Major Freeth ventured to predict what might begin to happen in two or three years, if anyone would be found with sufficient courage to tackle the problem in earnest. First, he referred to the question of a prime-mover. During our lifetime we have seen great changes taking place in the prime-mover. We have seen the steam-engine advance enormously in efficiency owing to the use of the turbine, which again is threatened by the Diesel engine. He predicted that there was very little except money and courage standing in the way of the immediate development of the gas turbine, and, if there is anything standing in the way, the opposition will come from the metallurgist, who will say he is not possessed of the materials capable of standing up to the rigorous conditions which will be required. Major Freeth further prophesied that in ten years' time we shall see the gas turbine, or something like it, utilising between 40 and 45 per cent. of the heat efficiency of the fuel in the form of mechanical energy on the shaft. He reminded us that the efficiency of an engine depends upon the initial and final temperatures of the thermodynamic fluid employed, and not essentially upon its pressure. If we can find materials which will stand up to largely increased temperatures—and there are many such, and new ones are constantly appearing,—he could see no valid reason why we should not secure a very greatly increased efficiency in our prime-movers.

On the question of the strength of metals, everyone recognised that a metal is not as strong as it ought to be, and he suggested the probability that within the next ten years we will be possessed of metals and alloys of a much greater strength than we have at present, and that this will come about almost entirely by improvements in technique.

B.S. Specification for Structural Steel.

(B.S.S. No. 15—1930).

THE new revised edition of the British Standard Specification for Structural Steel for Bridges and General Building Construction, B.S.S. No. 15—1930, has just been issued by the British Engineering Standards Association. The first edition of this Specification appeared in 1906, and this was revised in 1912. In the present revision a number of modifications have been made, of which the principal are the following :—

(i.) All reference to the basic Bessemer process is now omitted.

(ii.) Drawn-steel wire from 0·5 in. to 0·125 in. in diameter and which has subsequently been suitably heat-treated to enable it to conform with the requirements of this Specification is now included. Hard-drawn steel wire for concrete reinforcement, not so treated, is dealt with under Specification No. 165.

(iii.) A tensile test, in addition to a bend test, is required for bars for concrete reinforcement.

(iv.) Temper-bend tests are not now specified.

(v.) The radius of the bend in the cold-bend test has been made smaller for bars of 1-in. diameter and under.

(vi.) Tolerances on the specified depth of beams and channels have been inserted.

Copies of this Specification No. 15—1930, may be obtained from the British Engineering Standards Association, Publications Department, 28, Victoria Street, S.W. 1, price 2s. 2d. post free.

Rapid Blast-Furnace Reconstruction.

What is believed to have been a record in blast-furnace reconstruction work has been accomplished at the plant of the Weirton Steel Co., Weirton, W. Pa. The stack rebuilt was blown in on April 2, according to the *Iron Trade Review*, after being shut down for 91½ days, and on the ninth day after being started produced 1,105 tons, compared with its former nominal capacity of 600 tons daily. The general engineering and design work associated with this rebuilding was prepared by the engineering department of the Weirton Steel Co., and the construction of the furnace and new cast house was carried out by the McClintic-Marshall Co. The new furnace has the following dimensions :—

Hearth diameter, 25 ft. 6 in. ; bosh diameter, 29 ft. ; stockline diameter, 19 ft. 4 in. ; large bell diameter, 14 ft. 2 in. ; centre line of iron notch to top ring, 91 ft. 6 in.

The furnace is supported on 16 cast-iron columns, and is blown with 16 tuyeres.

General Refractories Ltd.

At the annual general meeting of this company, which was held in Sheffield recently, the Chairman, Mr. Frank Russell, F.G.S., said it seemed to be generally agreed that what British industry needed more than anything else was modernisation and re-equipment in order to reduce costs and permit competition with foreign producers, and he submitted that the company's present policy, which was to increase profits by producing at a lower cost, was the soundest they could adopt. The re-equipment they had already effected had been so successful that the Board were convinced that the policy must be applied at the earliest possible moment to the whole of the plants under their control.

The Modern Blast Furnace and its Operation

The Use of Higher Blast Temperatures—Theoretical Considerations—Operating Results—Practical Difficulties—Future Developments.

By R. A. Hacking, B.Sc.

THE amount of air entering the modern blast furnace via the tuyeres is equal to approximately 5·8 times the weight of the carbon burned there, and in some of the latest units may reach a figure of the order of 150 tons per hour. This large weight of "raw material," whose sole function is to oxidise the carbon opposite each tuyere, is introduced at the lower end of the counter-current system. It has already been recognised that the intensity of temperature at this point is the chief factor determining the economy of the process as a whole.

It has been shown that the head of temperature in the "combustion zone" is dependent mainly upon the speed of reaction between the carbon of the coke and the oxygen of the air blast. The carbon entering the zone has already travelled the full length of the counter-current, and during this migration :—

(1) It has benefited from a chemical standpoint by drying, and deteriorated to some extent by slag impregnation.

(2) It has benefited enormously from a thermal standpoint by being preheated practically to the temperature of the "combustion zone" itself.

On the other hand, the air entering the zone obviously cannot receive any benefit chemically or thermally from the furnace itself, but is dependent for improvement in its capacity as a reactant solely upon external means.

From the magnitude of the amount of air used, and from the fact that it is introduced into the counter-current system at its most vital point, it is evident that the "air factors," which define its condition, are of great importance in determining the efficiency of the blast-furnace process.

The Air Factors.

These may be enumerated as follows :—

(*a*) The temperature of the air blast.
(*b*) Its moisture content.
(*c*) Its oxygen content.
(*d*) The pressure at which it enters the furnace.
(*e*) Its velocity at the nose of the tuyeres.

The factors will now be discussed in the above sequence.

The Influence of Air-Blast Temperature.

The effects of an increase in blast temperature upon the conditions obtaining in the "combustion zone" are as follows :—

(*a*) Taking the unit of carbon oxidised as a basis, the input side of the thermal balance sheet of the zone benefits to the extent of the additional sensible heat of the blast, whilst the weight of the products of combustion remains constant. This results in an increase in the temperature of the zone.

The theoretical temperature of combustion of pure carbon oxidised to carbon monoxide by dry air containing 23% oxygen and 77% nitrogen by weight, is shown plotted against air-blast temperature in Fig. 3. The heat of formation of CO, and the specific heats used in the calculations are those given by Richards. The horizontal dotted line, indicating "critical temperature," is at the temperature level quoted by Johnson, namely, 2750° F.

It will be seen from the graph that an increase in blast temperature of 100° F. raises the theoretical temperature of combustion by 84° F. Further, the whole of the additional heat is available over the "critical temperature." In actual practice, however, this effect is lessened to some extent by the presence of slag and iron, by the occurrence of other reactions in the hearth, and by conduction and radiation losses.

(*b*) The speed of reaction between the carbon of the coke and the oxygen of the blast is increased on account

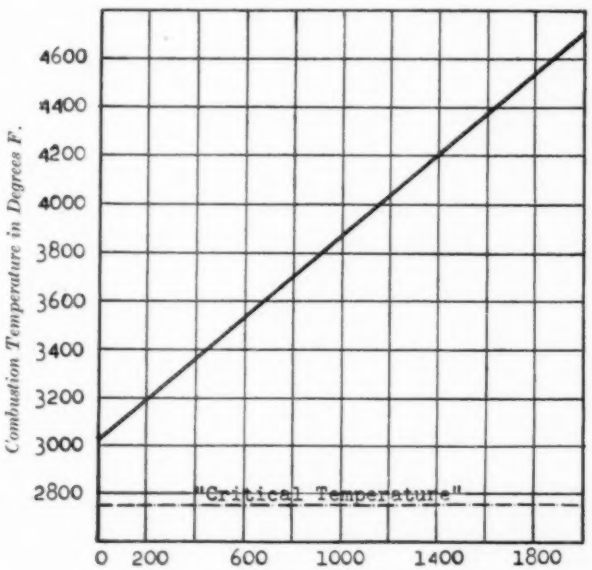


Fig. 3. Blast Temperature in Degrees F.

of the greater activity at the higher blast temperature. The dimensions of the "combustion zone" are therefore diminished, and the temperature in the zone is increased.

(*c*) The number of thermal units added to the system per unit of carbon burnt is increased. The effect of this is obvious. Assuming that the total number of B.th.u's. required per ton of pig iron remains constant, the sensible heat of the blast lessens the demand for B.th.u's supplied by the combustion of carbon, thus leading to a reduction in the weight of fuel used per ton of pig iron.

Lowthian Bell, and other observers of the later years of the nineteenth century, endeavoured to account for the great economies arising from the use of hot blast by considering only item (*c*). The combined effect of items (*a*) and (*b*) was completely ignored by most observers of that period. Since that time, however, Johnson's "critical temperature" theory, amplified by the work of other authorities, has led to recognition of the fact that the chief reason for the economy of the hot-blast lies in the intensity of temperature which is facilitated in the hearth. The thermal addition itself, in terms of B.th.u's., whilst important, is a subsidiary factor. In other words, the effect effect of item (*a*), assisted to some extent by that of (*b*), is more important to the economy of the process than that of (*c*).

Practical Considerations Regarding Hot Blast.

It is obvious from the above that it is desirable to heat the air blast to as high a temperature as possible. By this means the weight of fuel required, the weight of air blown, and the weight of gas generated at the tuyeres, per ton of pig iron, may be reduced.

In practice, however, the extent to which the use of higher air-blast temperatures may be exploited is dependent upon many considerations. So far as the furnace itself is concerned, the chief factors determining this limit are the character of the burden and fuel, the burden/fuel ratio, the type of pig iron produced, and the internal lines of the furnace.

Most blast-furnace operators find that with increasing blast temperature a point is reached at which hanging and slipping commence, with disastrous results to regular working, output, and quality of product. This limit ranges from about 1150° F. with basic iron, especially when the latter is smelted from an ungraded lean burden high in phosphorus and manganese, to about 1400° F. in the case of foundry and hematite practice. The blast temperatures used in the majority of cases are in general maintained a safe distance away from the "sticking" point, say 50 to 100° F. below.

In Table 2 the blast temperatures used at various basic-pig-iron furnaces throughout the world are given, together with other data indicating the essential features in each case. The figures are extracted from "Blast-furnace Practice" (F. Clements), and are reproduced by king permission of Messrs. Ernest Benn, Ltd. They are arranged in increasing order of blast temperature.

It is advisable at this point to survey briefly the effect of an increase in blast temperature, accompanied by a *pro rata* increase in the burden/fuel ratio, upon the thermal conditions above the hearth. It has been shown that the effect of an increase in blast temperature is to :—

(1) Lower the weight of carbon required to be burnt at the tuyeres.

(2) Lower the weight of gas passing upwards from the "combustion zone."

(3) Increase the initial temperature of this gas.

Of the descending solids, only the amount of coke is reduced *pro rata* with the gas volume. Thus, the fall in temperature of the gases per foot rise is increased, and the temperature at successive levels beyond a certain point is lowered.

If conditions at the bosh line are taken as a standard for comparison, it is evident that for successful operation under a given set of circumstances the temperature at this level must be maintained within relatively narrow limits. If the bosh line lies above the point at which the additional superheat of the ascending gases is dissipated, the temperature falls below the critical range and tight intermittent working is the result.

This apparent limit to the use of higher blast temperatures calls for improvement of the practice in other directions, before further progress can be made along the lines of "heat compression."

In a furnace of given interior lines the obvious move is to improve the opportunity for thermal interchange in the shaft by crushing and grading the materials of the charge. By this means the lag of the descending solids behind thermal equilibrium may be decreased, and the temperature at the bosh line, and at other levels in the furnace, may be maintained within the safety limits incidental to the practice by a smaller gas volume evolved from a smaller weight of carbon burnt with hotter blast at the tuyeres, per ton of pig iron.

In passing, the constant or intermittent use of bosh tuyeres as a remedy for hanging in basic furnaces calls for comment. It will be noted, from Table 2, that the highest blast temperatures recorded there are on furnaces 10 and 11, where bosh tuyeres are in constant use. It appears that the bosh-line temperature is maintained within safety limits by the "boosting" effect of a second smaller zone of combustion at that point. The fact that continuous running is obtained with blast temperatures as high as 1350° F. would appear to make out a good case for the use of bosh tuyeres in basic-pig-iron practice. At the same time bosh tuyeres in themselves obviously violate the "principles of heat compression," as evidenced by the observed exit-gas temperatures in Table 2. The top temperature is noticeably higher in those basic furnaces where bosh tuyeres are in constant use. It is not denied, however, that in certain circumstances bosh tuyeres may pay their way.

In recent years some of the latest American furnaces of improved interior lines, and equipped with stoves using cleaned gas, mechanical pressure burners, and the latest types of chequer brick, have been worked with blast temperatures which were hitherto unattainable. Moreover, it has been found that "sticking-up" occurs only over a comparatively small range of blast temperature, and that if the latter is increased through and beyond this range normal operation is again attained. It appears that the gas generated at the tuyeres leaves the "combustion zone" with a degree of superheat sufficient to offset its reduced weight per ton of product. Air-blast temperatures of over 1600° F. have given successful results in the form of increased output and reduced fuel consumption on furnaces of suitable design.

Interior lines play an important part in determining the extent to which the use of higher blast temperatures may be applied. The tendency to the lower steeper-walled bosh during the whole period since Neilson's time has arisen solely from application of the "principles of heat compression."

(To be Continued.)

TABLE 2.

OPERATING DATA OF FURNACES PRODUCING BASIC PIG IRON IN VARIOUS PARTS OF THE WORLD.

Furnace No.	Blast Temperature. ° F.	Bosh Tuyeres.	Exit Gas Temperature. ° F.	Iron Yield of Burden. %	Coke per Ton of Pig Iron. Lb.	Slag per Ton of Pig Iron. Lb.	Analysis of Pig Iron Produced.			
							Silicon.	Sulphur.	Phosphorus	Manganese.
1	572	Used in emergency only	374	47	1915	1568	0·1 to 0·5	0·05 to 0·10	0·10	2·0 to 3·0
2	1040	None	380	34	2790	2520	1·15	0·055	1·65	1·70
3	1040	In constant use	637	49	1760	1235	0·58	0·035	0·128	2·96
4	1100	None	300	41	2000	1100 to 1300	1·05	0·03	0·225	1·26
5	1125	None	425	41	2598	1426	1·0 to 3·0	0·025 to 0·04	0·35 to 0·40	1·25 to 1·50
6	1140	None	353	42	1759	967	0·91	0·037	0·172	1·83
7	1150	None	375	44	1922	1120	1·20	0·03	0·26	1·27
8	1161	Used in emergency only	518	40	2300	1773	0·7	0·015	0·20	3·30
9	1175	None	400	46	2152	1100 to 1200	1·0	0·034	0·192	2·07
10	1319	In constant use	598	43	2304	1680	0·5 to 0·8	0·05 to 0·08	2·0	2·0
11	1350	In constant use	550	39	2184	1680 to 1792	0·70	0·07	1·5	1·5

Heat-Resisting Cast Iron

By J. W. Donaldson, D.Sc.

Finding a cast iron of suitable composition to resist growth and reduction in strength resulting from repeated heatings and coolings is the problem of the cast iron metallurgist.

DURING the last thirty years the influence of temperature on cast iron has been the subject of numerous investigations. The fact that castings of grey iron, one of the most widely used of metallurgical materials, increase in size after repeated heatings and coolings, and that those increases in volume are accompanied by loss in strength and hardness is known to all users of this alloy. The explanation of the changes taking place, and the problem of finding an iron of a composition which will resist this tendency to increase in volume and decrease in strength, has been the work of the cast iron metallurgist.

The pioneer work of Charpy and Grenet[1] in 1902 established the fact that under the action of heat, whether above or below the critical range, grey cast iron undergoes a permanent non-reversible increase in volume, and that this increase is due to graphite decomposed from the cementite. Experiments by Outerbridge[2] confirmed this, and were followed in 1909 by the investigations of Carpenter and Rugan[3], who concluded that growth was chiefly due to oxidation of silicon and iron, and partly due to decomposition of cementite and partly to occluded gases. Later, investigations by Okochi and Sato[4] state that the pressure of occluded gas is the principal cause of growth, decomposition of cementite being only a partial cause, while oxidation is unimportant. These investigations were followed by the work of Kikuta[5], who attributes volume changes on the first heating to decomposition of cementite, and on subsequent heatings to different microportions, with irreversible expansions, causing fissures and minute cavities in the vicinity of the graphite. Growth is also stated to be partially produced by oxide formed by indirect oxidation filling the cavities and fissures during the transformation.

Volume Changes.

Andrew and Hyman[6] conclude that volume changes take place in two different stages. The first or rapid stage being oxidation of free graphite, which is replaced by oxide, the latter sealing up the graphite channels. Graphitising elements such as silicon, nickel, and aluminium increase growth, while chromium retards and reduces growth, but does not prevent it. Later work by Andrew and Higgins[7] shows that oxidation of iron precedes oxidation of graphite, and the spaces originally filled with graphite are filled with oxide of iron. Growth is also augmented by decomposition of the combined carbon.

The results of Pearson's[8] investigations on commercial cast irons indicate that volume changes are caused by oxidation of silicon and iron, and the higher the silicon the greater the change. The initial size of the graphite flakes appears to have an influence, and absence of oxidising influences, such as heating in a hydrogen atmosphere or in vacuo, only leads to small volume changes, which are attributed to occluded gases.

Benedicks and Löfquist[9], after reviewing the work of various investigators, give a theory of growth for cast irons when repeatedly heated. They state that no volume changes will occur unless cast iron is subjected to repeated heatings and coolings, including the critical range, and on account of internal burstings round the graphite flakes the contraction at the Ac decreases more rapidly than the expansion at the Ar, giving rise to a residual expansion with every heating cycle. Successively increasing internal burstings and fracturings permit the access of oxidising gas which gives rise to further growth, as does also increase in volume produced by decomposition of cementite.

Although the above authors (Benedicks and Löfquist) state that no growth takes place unless cast iron is heated through and above the critical range, it is well known, as first shown by Charpy and Grenet[1], that volume changes take place at temperatures considerably below the lower critical point. Campion and the Author[10] have shown that at 550°C. a volume change of 1·6% can occur, while Higgins[11] also found considerable volume changes working with two series of irons at 600°C.

Results Considered.

Consideration of the results obtained from the various volume change or growth experiments shows that resistance to growth is primarily related to the stability of the cementite, whatever may be the secondary and subsequent causes. If stability and cementite are the primary causes of change, then the composition of cast iron plays an important part in those volume changes, as the stability of the cementite under temperature is largely affected by the various elements present. Stability of cementite also affects the strength, and it has been shown by Hurst[12] that there is a broad relationship between resistance to growth and a strength factor.

The earliest investigations showing the effect of heat-treatment on strength are probably those of Hatfield[13]. Later work by Hurst[14], Schuz[15], Campion, and the Author[10] have shown that when grey cast iron is heat-treated at temperatures below and above the critical range decomposition of combined carbon takes place, and this decomposition is accompanied by decreases in the strength and hardness, and that decomposition depends on the silicon content of the iron. Silicon, however, is not the only element to affect combined carbon decomposition, and in order to investigate the effects of other elements, and at the same time to correlate combined carbon decomposition with loss in strength and hardness, and with volume changes, the Author[16] carried out a large number of heat-treatment experiments at temperatures below the critical range.

Four series of cast irons with varying contents of one of the elements, total carbon, manganese, phosphorus, or silicon were heat-treated at 450° C. and 550° C. for periods of five days of eight hours each, being allowed to cool overnight. Decomposition of combined carbon resulted, the tensile strength and Brinell hardness being affected to an extent depending on the temperature, duration of heating, and composition of the cast iron, equilibrium being reached after 200 hours. Four of the irons were heat-treated at temperatures rising by 50° C. from 200° C. to 450° C., when it was found that little change took place below 200° C., except over a very long period of time. The stability of the combined carbon, and consequently the resistance to heating, decreased with increase in total carbon content from 2·71 to 3·51%; whereas increase of manganese from 0·52 to 2·43%, and of phosphorus from 0·20 to 1·06% increased the stability of the combined carbon, with consequent increase in the heat resistance.

With less than 1·10% silicon the stability of the combined carbon was very noticeable, and increased as the silicon content decreased, to 0·65%. A critical content of silicon for combined carbon decomposition lies between 1·10 and 1·17%, as over this percentage decomposition takes place rapidly, and is complete with an iron containing 2·2% silicon.

In the heat-treatments at 550° volume changes took place during the first 40 hours heating, and were due to the decomposition of the combined carbon and also proportional to that decomposition, being followed during further heatings by penetration of air along the graphite flakes and the consequent oxidation in their neighbourhood producing a secondary volume change. With a low total carbon content growth is small, increase in the manganese content is accompanied by slight increase in volume, while increase in phosphorus decreases the volume change. A silicon content of 1·1% or less produces a small expansion, which becomes more pronounced and is accompanied by oxidation of the iron when the silicon is increased from 1·2 to 1·5%, and becomes very pronounced in cast irons containing 1·5 to 2·2% silicon.

Stability of Combined Carbon.

When the results of these experiments are considered, the relationship between combined carbon decomposition, strength, and volume changes is apparent. The vital factor in the heat-resistance or otherwise of cast iron is the stability of the combined carbon, and composition plays an important part in producing this stability. A low total carbon content and silicon below 1·1% are the principal factors.

Low total carbon involves certain difficulties in manufacture which have to be considered. These difficulties are usually overcome in ordinary practice by the use of steel in the mixture, or the using of specially refined pig iron. Manufacture in certain special types of cupolas or in air-furnaces is also helpful. Low total carbon, besides improving the heat-resisting and growth properties of cast iron, also adds to the strength properties of the material, tensile strengths of over 20 tons per square inch being obtained with irons containing 2·75 to 3·0% total carbon. The wearing properties of cast iron are also improved by a low carbon content.

The manufacture of cast iron with low silicon also produces difficulties in ordinary foundry practice, resulting in the production of hard unmachineable irons, or irons containing hard spots which give considerable trouble on machining. With 0·8 to 1·1% silicon little difficulty should be experienced provided the proper melting conditions are attained and pouring temperatures regulated, except in the case of very thin sections. With under 0·8%, however, a hot-mould process is necessary, and by such a process grey cast iron, uniform in structure throughout the various sections and easily machineable, can be obtained with as low as 0·4% silicon. The heat-resistance of such an iron is extremely high at all temperatures.

Other Constituents.

With regard to the other constituents of cast iron, the combined carbon, which depends chiefly on the total carbon and silicon as regards composition, and on the rate of cooling as regards practice, should be between 0·8 and 0·9%. The graphitic carbon should be in as finely divided state as possible. The phosphorus content should not exceed 0·5%, and the sulphur 0·08%. While high phosphorus is not detrimental to volume changes, a low phosphorus is necessary if the material has to withstand impact, as many heat-resisting engineering castings have. The percentage of manganese most suitable for heat-resisting cast iron is more doubtful. The use of 1·5 to 2·5% manganese has been advocated; but while there is no doubt that manganese stabilises the combined carbon, if decomposition of the carbon does take place there is more tendency to volume changes due to the decomposed manganese carbide oxidising readily. The manganese content is best kept within the limits 0·5 to 1·0%.

The addition of special alloying elements has been considered to increase the heat-resisting properties of cast iron, but little systematic work has been done on them with the exception of chromium. The Author[17] has investigated the effect of chromium up to 0·90% in the presence of 1·5% silicon, and found an increase in the stability of the combined carbon at temperatures up to 550° C. This increase in stability, probably due to the presence of chromium carbide in the cementite of the pearlite is reflected in the increased strength and hardness. There is, however, difficulty in machining irons with over 0·4% chromium. The influence of chromium on volume changes at temperatures below the critical range is erratic, but the general effect is to produce a contraction, the nature of which is difficult to explain or define.

Tungsten tends to exert a similar effect to chromium, but is expensive and more difficult to alloy. Nickel and vanadium behave like silicon in producing combined carbon decomposition, increasing oxidation of the iron and accelerating volume changes, although for an equal content their action is not so pronounced. Better results have been obtained in iron containing both chromium and nickel; the hardening and retarding influence of chromium being counteracted by the graphitising and oxidising effect of nickel.

Other iron alloys have been recommended for heat resistance. It has been announced recently by the British Cast Iron Research Association that remarkable results have been obtained with alloys not previously recognised as possessing heat-resisting properties. These have been tested in the laboratory and on an industrial scale at temperatures of 600°—1,000° C. The results obtained are claimed not only to modify existing views regarding composition on volume changes, but to have led to a clearer conception of the nature of growth.

1 G. Charpy and L. Grenet, "Engineering," 1902; vol. 73, p. 626.
2 A. E. Outerbridge, "Trans. Amer. Inst. Min. Met. Eng.," 1905; vol. 35, p. 223.
3 H. C. H. Carpenter and H. F. Rugan, "Jour. Iron and Steel Inst.," 1909; vol. 2, p. 29.
4 M. Okochi and N. Sato, "Jour. Coll. Eng. (Tokyo)," 1920; vol. 10, p. 53.
5 T. Kikuta, "Science Reports," Tohoku Univ.," 1922; vol. 11, p. 1.
6 J. H. Andrew and H. Hyman, "Journ. Iron and Steel Inst.," 1924; vol. I, p. 451.
7 J. H. Andrew and R. Higgins, "Jour. Iron and Steel Inst.," 1925; vol. 2, p. 167.
8 C. E. Pearson, "Jour. Iron and Steel Inst., Carn. Schol. Memoirs," 1926; vol. 15, p. 281.
9 C. Benedicks and H. Löfquist, "Jour. Iron and Steel Inst.," 1927; vol. I, p. 605.
10 A. Campion and J. W. Donaldson, "Proc. Inst. Brit. Found.," 1921-22; vol. 15, p. 211.
11 R. Higgins, "Jour. Iron and Steel Inst., Carn. Schol. Memoirs," 1926; vol. 15, p. 217.
12 J. E. Hurst, "Foundry Trade Journal," 1925; vols. 32, p. 21; 1926, vols. 34, p. 137.
13 W. Hatfield, "Cast Iron in the Light of Recent Research," p. 154.
14 J. E. Hurst, "Jour. Iron and Steel Inst.," 1917; vol. 2, p. 121.
15 E. Schuz, "Stahl u. Eisen," 1922; vol. 42, p. 1,481.
16 J. W. Donaldson, "Bull. de l'Assoc. Tech. de Fonderie," 1928; vol. 2, p. 257.
17 J. W. Donaldson, "Foundry Trade Journal," 1929; vol. 40, p. 489.

American Foundrymen's Convention.

The Annual Convention of the American Foundrymen's Association, held at Cleveland from May 12 to 16, is the fourth occasion, since the inception of the organisation, that Cleveland has been responsible for the annual convention. The public auditorium, at which the meetings are held, will also house an extensive exhibition of foundry equipment, which is associated with the convention. A wide range of subjects directly concerning the foundry will be considered at the convention, among which is the presentation of the exchange paper of the Institute of British Foundrymen by J. G. Pearce, B.Sc., Director of the British Cast Iron Research Association. His paper will deal with the "Correlation of Tests for Cast Iron."

An interesting feature of the convention is the organisation of a shop operation course, which is arranged to include discussion of problems arising from the cast iron, steel and non-ferrous sections. The subjects for discussion cover cupola materials and operation, alloy additions and heat-treatment, high-duty irons, and gates and risers in connection with cast iron. The steel course includes the fitting of castings and riser removal, core-room practice, and practical aspects of heat-treating. Practical topics in non-ferrous work include various types of melting furnaces.

Reviews of Current Literature.

Outline of Metallurgical Practice.

IT is recognised that many treatises are available on all the common metals and handbooks of metallurgy which cover to a varying degree the base and rare metals. In addition to these works there are books, monographs, and technical papers confined to separate phases of metallurgy of many of the metals. These provide a wealth of material and information for the discriminating metallurgist or student. This new work has been designed to occupy a new field, rather than to replace any work which has previously appeared, and it is claimed that it will satisfy two demands. First, to meet the desire of many engineers for a quick reference book which will give modern practice in extracting and refining most of the metals, and also give general information regarding the sources, uses, and important alloys of the metals. Second, to assist students commencing the study of metallurgy, with no practical experience and little or no knowledge of the subject and its literature.

There is no doubt that the initial difficulties of the student in grasping fundamental principles and practices are very considerable, in view of the variety of processes, some of which are obsolete, some in use, and others merely proposed but not yet accepted commercially. Any work of this character which facilitates study and gives a clearer conception of modern practice in metallurgy, at the initial stage, serves a very useful purpose, as it reduces the possibility of confusion that is almost inseparable from the use of a complete treatise at the preliminary stage.

As the title of this work implies, it is not intended as a complete treatise on the subject, but rather as an outline, and, in order that the fundamental principles may be fully grasped, it deals with the subject in rather an elementary manner. To bring the matter within the compass of one volume, having 612 pages, long descriptions of apparatus and details of processes have been eliminated, while processes of historical or of minor interest are either omitted entirely or are only given very brief reference.

Copper is the first metal discussed, and it is treated at much greater length than the other non-ferrous metals, the section occupying 124 pages. This is due mainly to the fact that certain general operations described and illustrated are common to other metals, and only need minor reference in further chapters. Another comprehensive section is that dealing with iron and steel, to the discussion of which 116 pages are allocated. Each section of the work is subdivided under separate headings. Thus, for instance, in the copper section the sub-headings include native copper, sulphide ores, oxide ores, mining, crushing, concentration, roasting, smelting, converting copper matte, refining blister copper, electrolytic refining, melting and refining the cathodes, treatment of the slime from electrolyzing, notes on refining practice, smelting native copper ore, smelting oxide copper ores, electric smelting, leaching sulphuric acid, leaching with ammonia and ammonium carbonate, leaching with ferric salts, leaching with hydrochloric acid, leaching with sulphur dioxide, precipitants, heap leaching, leaching ore in place, stope leaching at Cananea-Mexico, leaching at Ajo Arizona, leaching at Chuquicamata, leaching mixed copper ores with an acid solution of ferric sulphate, leaching oxide and native copper ore with ammonia and ammonium carbonate, leaching sulphide ores with sulphuric acid after roasting, leaching a chloridized ore with solution containing hydrochloric acid, physical properties, and mechanical properties.

The other metals are dealt with similarly, excepting that where identical processes are used as for copper the reader is referred back. A useful section at the end of the book deals particularly with non-ferrous alloys, which gives many equilibrium diagrams and photomicrographs.

An interesting feature is the suggestions for supplementary reading appended to each section to guide students in pursuing researches with any metal. The work is well illustrated, having over 400 drawings and photographs reproduced, and many of them are used primarily to give assistance to the reader lacking plant experience, and also to limit descriptions of processes and apparatus.

There is no doubt that this work will prove of considerable value to students of metallurgy and provide a very useful means of reference for the experienced engineer who desires information without the constant need for concentration on a more complete treatise.

By Carle R. Hayward, Associate Professor of Metallurgy, Massachusetts Institute of Technology. Published by The Library Press, Ltd., 83, Southwark Street, London, S.E. 1. 30s. net.

Proceedings of the Institute of British Foundrymen.—Vol. XXII.

THE recently published proceedings of the Institute of British Foundrymen contains a full report of the International Foundryman's Congress and the twenty-sixth annual conference, held in London from June 10 to 14, 1929. It also contains papers and discussions presented at branch meetings held during the session 1928-1929. The international congress represented the third occasion on which the foundrymen of the world had been brought together to study problems bearing on the complex industry of founding, which is the basis of every mechanical engineering activity. In addition to a very excellent address by the President of the Institute of British Foundrymen, Wesley Lambert, A.K.C., F.I.C., exchange papers were presented by J. W. Bolton, M.Sc., on behalf of the American Foundrymen's Association, A. Le. Thomas, and R. Bois, on behalf of the French Foundry Associatiou, and Professor E. Diepochlag, of the German Foundry Owners' Association, as well as from representatives of Holland, Poland, and Czecho-Slovakia, which emphasised the international character of the proceedings. All the papers presented at the Congress, as well as discussions arising from them, are published in full.

Different problems relating to various aspects of cast iron predominate, but other important metallurgical fields are not overlooked; thus die-castings, cast bronzes, and steel castings are considered, together with the application of pulverised fuel to metallurgical furnaces. Included among many papers given at various branches of the Institute of British Foundrymen and published in these proceedings are three papers that have earned for their authors diplomas of the Institute.

Hard-drawn Copper Conductors for Overhead Power Transmission Purposes.

BRITISH Standard Specification, No. 125-1930, Hard-drawn Copper Solid and Stranded Circular Conductors for Overhead Power Transmission Purposes, has recently been issued. This is a revision of the 1924 edition, and differs from the previous issue only in certain minor points of an editorial nature designed to bring it into line with the 1930 revision of the B.S. Specification for Aluminium Conductors for Overhead Power Transmission Purposes, No. 215.

Specification No. 125 lays down standards for Copper Conductors with regard to the mechanical and electrical properties required for overhead power lines and prescribes tests to ensure compliance with these requirements. The sizes of conductors are given in separate tables for primary and secondary standards, respectively, these tables being unaltered from the previous edition.

Copies of this specification may be obtained from the British Engineering Standards Association, Publications Department, 28, Victoria Street, S.W. 1. Price, 2s. 2d. post free.

MELTING IRON IN THE CUPOLA.

We have been asked to state that the above work by J. E. Hurst, and published by the Penton Publishing Co., of Cleveland, Ohio, which was reviewed in the April issue of our journal, is available at the European offices of this company, Caxton House, Westminster, London, S.W. 1, the price being 25s. net as stated.

Nitrogen Case-Hardening of Steel by The Homo Method.

CONSIDERABLE interest has been shown in case-hardening special steels by means of ammonia gas. The process, which is commonly referred to as nitrating, consists in subjecting the machined and, preferably, heat-treated articles to the action of ammonia gas under certain conditions, as a result of which remarkable surface hardness is imparted to the material without any further heat-treatment.

The temperature to which the articles are subjected during the nitrating period is relatively low—500° C.,—and in consequence no appreciable warping or distortion is likely to take place, provided that all strains produced in machining and in hardening have been removed. The articles to be case-hardened should be machined and heat-treated to give the required physical properties to the core. All traces of decarburization, and all strains must be eliminated before the subjection of the articles to the ammonia treatment.

The successful development of the process is due to researches carried out by Dr. Adolph Fry, which led to the discovery that by adding alloying elements, such as aluminium, chromium and molybdenum to carbon steel, the penetration of nitrogen could be controlled and restricted to the surface layers of the steel. In plain carbon steels the nitrogen completely penetrates the material and renders the whole part brittle. A series of steels having a range of carbon contents, and containing approximately 1·25% aluminium, 1·5% chromium, and 0·2% molybdenum, was developed, and are marketed under the name of "Nitralloy."

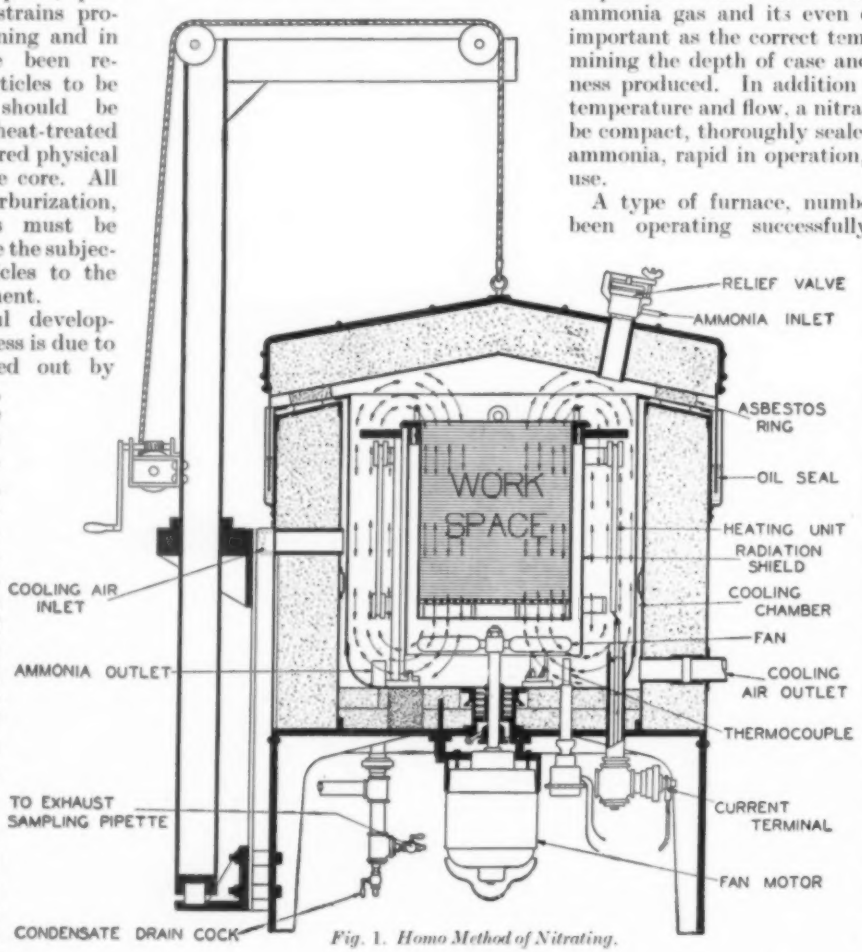


Fig. 1. Homo Method of Nitrating.

The equipment required for the case-hardening of articles with ammonia is of considerable importance to the success of the process. It should consist of a suitable furnace provided with automatic temperature control, a gas-tight container made from some material which will not be acted upon when exposed to ammonia gas at the nitrating temperature, a material such as chrome-iron, a tank of ammonia fitted with a suitable needle valve for controlling the flow of gas, inlet and outlet connections, and, in addition, a special pipette for determining the extent of the ammonia dissociation. Nitrating is a chemical process which is hastened by heat, and it is necessary that the temperature of each article treated, as well as the supply of ammonia gas to each article, should be closely controlled in any furnace that is required to operate on a production basis. Investigations in the process by Robert Sengerson, before the American Society of Steel Treating, have shown that a Vickers hardness of over 1,000 results from nitrating at 950° F., but on increasing the nitrating temperature to 1,000° F. the hardness is reduced to less than 800, and is further reduced to barely 400 on being treated at a temperature of 1,200° F. On the other hand, the depth of case increases with the rise in temperature.

Experiments have also shown that the flow of ammonia gas and its even distribution are as important as the correct temperature in determining the depth of case and the surface hardness produced. In addition to close control of temperature and flow, a nitrating furnace should be compact, thoroughly sealed against escape of ammonia, rapid in operation, and economical in use.

A type of furnace, numbers of which have been operating successfully for some considerable time in several important plants, has been specially designed for this class of work, and is known as the Homo nitrating furnace, which is manufactured by the Leeds and Northrup Co., the sole British agents being the Integra Co., Ltd. This furnace is illustrated in Fig. 1. The shell is completely sealed, and is gas-tight. Special materials have been used in its construction that do not disintegrate, as do the usual alloys, when in constant contact with hot ammonia gas. All the parts have been designed to facilitate economic use of the furnace, and the peculiar influence of the ammonia has necessitated special bearings, castings, and heaters in its construction.

In operating the furnace the articles are placed in a container which is lowered into the shaded work space shown in Fig. 1. This work chamber is surrounded with electric heating coils which are separated from it by a cylindrical radiation shield. Around the chamber is a passage through which compressed air is blown, at the end of a run, to cool the furnace quickly. An oil seal at the top ensures that the furnace is gas-tight. When the furnace has been loaded and the operation started, the ammonia gas enters through a port in the cover. The fan, operating at the bottom of the furnace, drives the gas through carefully designed passages that take it past the

(*Continued on page* 36.)

Some Recent Inventions.

DIRECT MANUFACTURE OF BILLETS.

IMPROVEMENTS have been devised for the production of billets, bars, blooms, slabs, etc., direct from the molten metal. The appliance is applicable to any metal, but particularly to iron or steel or steel alloys. These improvements consist in closing the upper face of a channel of suitable cross-section over part of its length to form a mould cavity, maintaining a continuous longitudinal movement between the channel and the closure device, simultaneously maintaining a supply of metal to the mould cavity to keep it practically filled, and automatically stripping the billet from the channel immediately after its emergence from the mould cavity and with or without previous solidification of the billet while still within the channel.

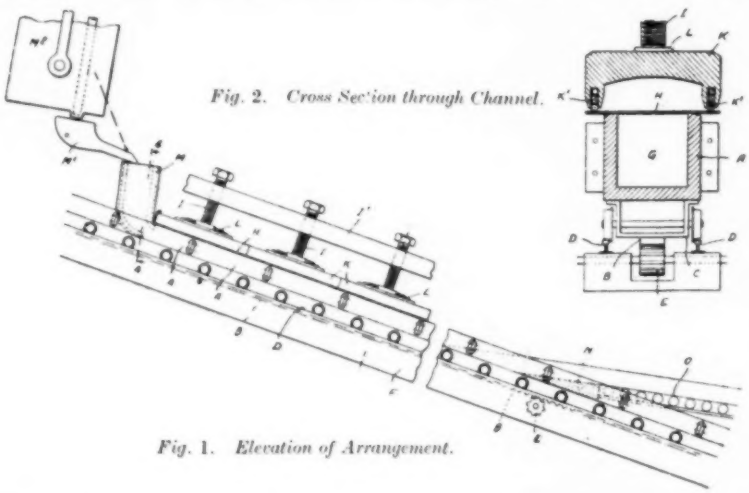


Fig. 1. Elevation of Arrangement.

Fig. 2. Cross Section through Channel.

In the apparatus for carrying out these improvements the mould channel is moved while the closure device is stationary and, in its preferred form, consists of a strip or band of steel, heat-resisting alloy, copper, or any metal of high melting point, which is anchored at one end to a fixed point and is sufficiently flexible to permit of it being pressed firmly along its whole length upon the face of the channel of the travelling mould. This is accomplished by means of a number of blocks of comparatively short length which are mounted so that they can be pushed against the closure strip and so ensure a tight joint between the latter and the edge of the mould channel. The billet may be passed under rollers after its emergence from the mould cavity and while still in the channel of the travelling mould in order to consolidate it to some extent before it is stripped from the mould. On the other hand the automatic stripper may be arranged to engage the billet before such consolidation when the mould has travelled a sufficient distance beyond the closure device to permit the solidified or partially solidified billet to be removed from the mould without blading by means of a stripper, rigidly fixed at a suitable angle, which frees the billet from the mould channel and delivers it to a conveyer or passes it between rolls. In the latter instance the rolls should be driven to rotate at a peripheral speed equal to or slightly faster than the speed of the moving mould.

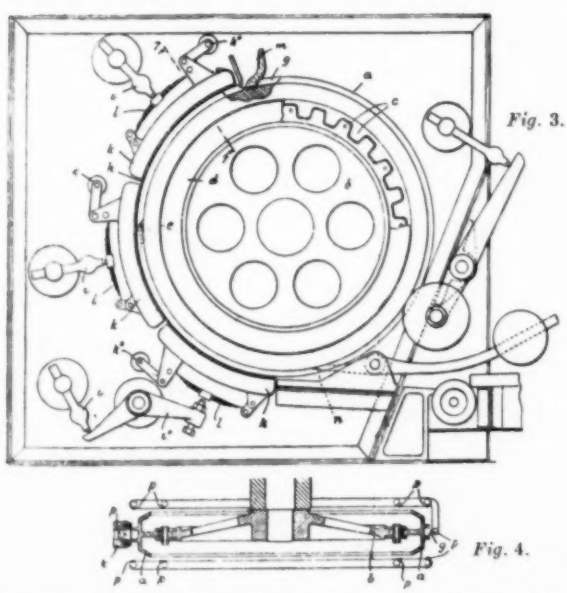


Fig. 3.

Fig. 4.

In the accompanying illustrations Fig. 1 is a diagrammatic elevation of the arrangement embodying a mould of the longitudinal or straight-line type. Fig. 2 shows an enlarged section of Fig. 1. The channel member, having movement relative to the cover and pourer, is formed of blocks at A which are connected together, carried by wheels D^1 and advanced by rack and pinion E. The cover may comprise recessed blocks K, with closing plates H and packing K^1, in Fig. 2, or hollow blocks may be used. The cover is pressed against the blocks A by springs L and screws I. Both channel and cover members are cooled internally or externally or both. The metal is introduced through a lined funnel M, Fig. 1, and in starting is retained at the other end by a plug of metal, fireclay, etc. The channel member moves at such a speed that the metal is sufficiently solidified to be removed by a stripper N, pass over a roller bed O, and be cut up by flying shears. In this arrangement of a straight-line mould the length of the billet is determined by the length of the mould, but it is possible to make billets of practically any length by means of a "continuous" mould.

In its simplest form this might consist of a circumferential groove formed in a cylinder which is rotatable in a controlled manner about a horizontal axis, the mould closure device being designed to fit closely against the cylindrical surface and to give the desired cross section to the mould cavity, the mould closure being separately supported to occupy a fixed position on the downwardly moving side of the cylinder and suitable means provided to press it firmly into contact.

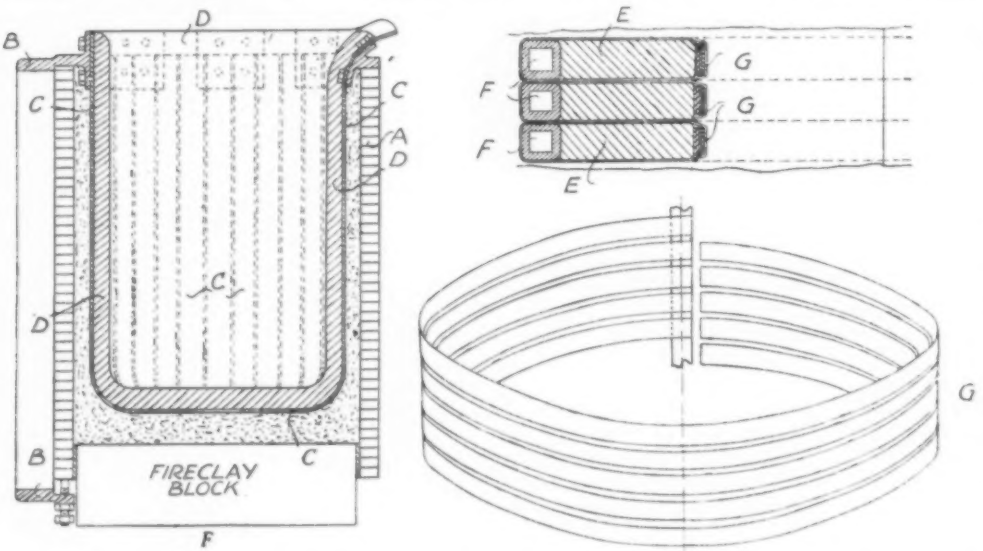
In practice, instead of having a circumferential groove cut or cast on a cylinder, it is preferable to have a detachable mould so mounted on a cylinder as to allow for unequal expansion and contraction. Such an annular or continuous mould is illustrated in Figs. 3 and 4. In this modification one or more channels are formed in an interchangeable rim A, Fig. 3, secured by teeth C and plates D to a rotary member B and cooled by water jets O, Fig. 4. The cover members K, Fig. 3, screws I and C are arranged to be easily swung aside for changing the rim for one of another section if desired.

In another modification the channel is spiral and the members have a relative spiral movement. The plug used when starting is preferably shaped as shown at E, to facilitate stripping, and if of clay, etc., may have holes into which molten metal runs. The solidified metal may be consolidated in the channel by a roller or the stripped metal may be compressed or modified in section by passing between rolls.

323,315. Patentees: F. W. HARBORD and V. HARBORD, of 16, Victoria Street, London, S.W. 1. Agents: Messrs. Abel and Imray, 30, Southampton Buildings, London, W.C. 2. January 2, 1930.

ELECTRICAL INDUCTION FURNACE IMPROVEMENTS.

WHEN a particular kind of induction furnace is in operation it is possible that the charge or electrically conducting parts of the furnace casing may accidentally become connected to the inductor coil and, consequently, may be subjected to an alternating electrical potential which would be dangerous to workmen who may have to perform operations on the furnace, such as slagging and charging it, during the progress of the heating. The kind of induction furnace referred to is that in which an alternating magnetic flux set up by an inductor coil links a charge to be heated and sets up circulating currents in it. In order to obviate any danger to workmen through electrically conducting masses associated with the furnace being subjected to a high potential derived directly from the inductor coil, an earthed electrically conducting screen has been devised, which is interposed between the charge and the inductor coil and/or between the furnace casing and the inductor coil.



This earthed screen should be so constructed that it does not present a continuous electrical current circuit embracing the charge or present dimensions greater than specified below, perpendicular to the magnetic flux of the inductor, at the point occupied by the shield. It may be constructed, for example, of wire netting, preferably made of some non-magnetic steel of high resistivity; on the other hand it may be a cast or pressed basket of iron alloyed with about 30% of nickel, known under the trade name of "Nicon" or the nickel-chromium-iron alloy containing about 20% of chromium and known under the trade name of "Staybrite." The screen may be formed from strips of non-magnetic conducting material arranged parallel to the axis of the charge, so that the eddy currents induced in the strips are minimised and the heat generated in them will not be excessive.

If the screen is in the form of metallic strips the cross-section of the strip should preferably be such that

$$\frac{w}{\beta} < 2 \quad \text{where} \quad \beta = \sqrt{\frac{\rho}{4\pi p}}$$

w is the diameter in centimetres of the largest circle which can be inscribed in the cross-section of the strip taken perpendicular to the direction of the magnetic flux at any part thereof.

ρ is the resistivity of the material employed for the strips in electromagnetic units and

p is the pulsatance, that is 2π multiplied by the frequency at which the furnace is energised.

The accompanying illustration Fig. 1 is a vertical section, somewhat diagrammatic, of a furnace having a screen of strips constructed in accordance with this device. The construction consists of an inductor coil A, which is supported between flanged rings B, B at top and bottom. The bottom of the furnace is formed by a block of fireclay. The screen C, as shown, is made of metal strips which are attached to the top ring B, and shaped at the bottom to conform with the crucible or chamber shape. Between the screen and the inductor coil and the supporting block is a lagging of sand or other refractory. The lining D which forms the crucible is sintered within the screen.

In the construction illustrated in Fig. 2 the inductor coil is formed of metallic strip, shown at E, wound edgewise and having a cooling channel F in the outer edge. The screen is closely adjacent to the inside of the inductor coil and is formed of helical rings shown at G. These rings are made discontinuous in order to reduce eddy currents and are insulated from the inductor. A method of constructing the screen consists in forming a series of helical rings, each of which is severed, one of the severed ends of each ring being connected to a vertical support, as illustrated in the diagrammatic view Fig. 3. The cross-sectional dimensions of the strips of metal forming the screen in this construction must conform to the formula previously referred to.

323,561. Patentees: NEVILLE R. DAVIS, of Woodcourt, Brooklands, Cheshire, and ASSOCIATED ELECTRICAL INDUSTRIES, LTD., Bush House, Aldwych, London. January 9, 1930.

PROTECTIVE DEVICES FOR ARC WELDING.

To the operator engaged in electric arc welding nothing is more important than protection for his eyes. A new device which during welding operations effects protection, has a protective shield arranged as a grid shutter of dark-coloured glass or mica adapted to be interposed automatically in the line of vision whenever the current is passing. The shield may be actuated by the current itself, or by a current proportional thereto, *e.g.*, by an electromagnet. Instead of being operated directly, the shield may be moved by a bulb release or a Bowden wire release under the control of a solenoid energerised by the current. The shield may be mounted in a mask or helmet to be worn by the operator, or may be mounted in front of the job, or attached to the welding stick.

325,586. British Thomson-Houston Co., Ltd., Crown House, Aldwych, London, and J. H. Warburton, 5, Boundary Road, Merton, Surrey.

MELTING METALS AND ALLOYS.

IN a process for heating or melting metals or alloys in an induction furnace of the usual ironless type, the material is subjected to a preliminary treatment to increase its conductivity, with a view to enabling the heating to be carried out by means of currents of low frequency.

325,940. C. Tama, 10, Nymphenburgerstrasse, Berlin, and Electric Furnace Co., Ltd., 17, Victoria Street, London.

Failure of a Crankshaft

By H. W. Keeble.

THE failure of any material in a machine is of important consequence as regards damage and human injury. The following causes of failure of a steel component are enumerated in the notes below by reason of their interest and desire of avoidance in the future. A crankshaft of $2\frac{1}{2}$ in. diameter was fitted to an air compressor, and it failed after 18 months' service.

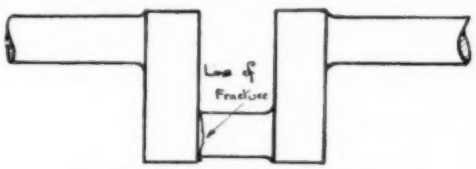


Fig. 1.—Showing Position of Fracture.

An examination of the type of fracture, its position, and the quality of the material of which the shaft was made, revealed defects in the design of the crankshaft, and in its quality and heat-treatment received. The results of the laboratory investigation were as follows:—

Chemical Analysis.—

Carbon	0·29%
Silicon	0·023%
Sulphur	0·055%
Phosphorus	0·045%
Manganese	0·52%

Physical Tests.—

Brinell hardness	123 kilos./sq. mm.
Ultimate tensile strength	29 tons/sq. in.

With regard to the chemical analysis, this may be considered quite a suitable composition for this class of material. Concerning the mechanical tests, both the Brinell and ultimate tensile strength values are low, being outside the range of the specification to which it was purchased, it being:—

Ultimate tensile strength	31–35 tons/sq. in.
Brinell hardness value	134–156 kilos./sq. mm.

The Fracture.—The fracture, as received, indicated failure by progressive fracture or fatigue, the final rupture taking place across an area of only approximately 2 sq. in., the total cross-section originally being 5 sq. in. The position of the fracture was rather significant, it occurring at the junction of the web and crankpin, see Fig. 1. The effect of the finish and design on the fatigue value is not always appreciated. The radius of the fillet at the point of fracture was of no use at all, it being very small and severely scoured by machining lines. It is insisted that where changes of section take place on high-duty mechanism, liberal radii must be used if the fatigue strength is not to suffer. Fig. 2 illustrates the researches of Moore and Kommers on the effect of the radius at the change of section on the fatigue limit, amplifying the previous statement. The rough finish of the radius would provide places of localised stress. Localised stresses are found at oil-holes, the base of screw threads, keyways, and notches, etc. Under static loads the effect of the finish is not appreciable to any degree, but under alternating or repeating loads they tend to become the nuclei of fatigue cracks. For this reason surface defects such as roaks, laps, and fashes, etc., should be eliminated on material which will, when in use, encounter alternating or reversing loads. Table I shows, comparatively, the effects of the finish on the fatigue range, compiled by Moore and Kommers. Undoubtedly the small radius, coupled with the extremely rough machining finish, was a contributory cause to the ultimate failure of the crankshaft.

TABLE I.

Type of Finish.	Relative Fatigue Range.
Rough Turned	81
Smooth Turned	84
Ground	89
No. 0 and 00 Emery Cloth	99
No. 0 Emery Cloth to No. 00 Emery Paper. Afterwards polished with Rouge	100

Material:—
0·49% Carbon Steel.
Maximum Strength 43·2 tons/sq. in.
Fatigue Range under best conditions ± 22 tons.

Micrographical Examination.—A specimen was cut from as close to the fractured area as possible. The photomicrographs, Figs. 3 and 4, reveal the structure of the steel as seen after polishing and etching. In Fig. 4 a defect is seen. It is a narrow hole containing slag or some non-metallic

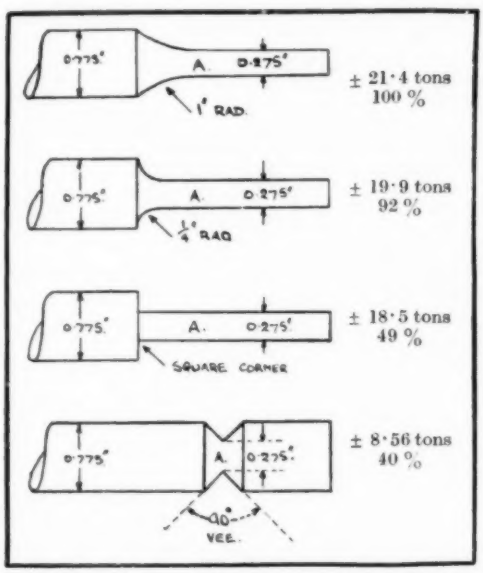


Fig. 2.—Effect of Radius at Change of Section on Fatigue Value. Material for this Test was a 43-tons per sq. in. Carbon Steel.

inclusion. Part of these may have been dragged out during the polishing process, producing the scour lines which are plainly visible on Fig. 3. However, from the general appearance of these holes in other parts of the specimen it seems not unlikely that they are the remains of shrink or draw holes in the original ingot. Although the defects in other parts of the sample are not so large as those shown in Figs. 3 and 4, there are quite a number of them. They appear as small dark spots in Fig. 3, which is a photomicrograph of the same defect taken at a higher magnification. With regard to Fig. 4 this shows the steel etched. The small dark areas are pearlite whilst the light background is ferrite. From the very angular formation of the pearlite it suggests that the shaft has been overheated to some extent during the forging or annealing operations. Around the non-metallic inclusion in the centre there is an area devoid of pearlite. This shows very forcibly the manner in which such inclusions weaken the steel. Their actual presence is, of course, a direct source of structural weakness, but besides this there is an indirect source, consequent upon the reactions of the inclusion with the carbon surrounding it so that the steel in the immediate

neighbourhood becomes decarbonised. Thus, there is an inclusion of no strength whatever surrounded by an area of practically carbonless material which has a strength much less than that of the adjacent normal steel.

Fig. 3.—Illustrating Defect × 280 diams. Unetched.

Conclusions.—The fracture indicates failure by fatigue, and the micrographical examination discloses that there are non-metallic inclusions present, filling in elongated shrink or gas holes, and the structure is overheated. In

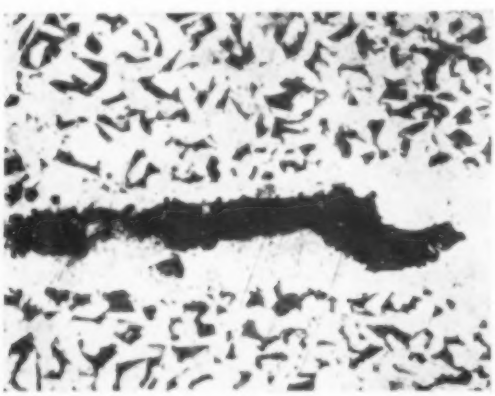


Fig. 4.—Decarburised Streak with Inclusion × 100 diams. Etched 3% Nitric Acid in Alcohol.

view of the above facts one can conclude that the steel was in a bad condition and, coupled with the inadequate radius and rough machining at the point of failure, caused the fracture.

Specification for Brass Tubes and Glands.

The British Engineering Standards Association has recently published a Specification dealing with brass tubes and screwed glands for condensers for land purposes upon similar lines to the Specification issued in 1921 for tubes and glands for marine purposes. The present Specification, however, provides for eight sizes of screwed glands, from $\frac{5}{8}$ in. to $1\frac{1}{2}$ in. inclusive, and has, as in the case of the Specification for marine purposes, clauses covering the quality of material, the dimensions of the tubes and the glands, and mechanical and hydraulic tests.

Copies of this Specification, No. 378–1930, may be obtained from the British Engineering Standards Association, Publications Department, 28, Victoria Street, S.W. 1. Price 2s. 2d. post free.

A programme for the study of experimental ingots made at Sheffield University is now in hand, and a grant of £2,000, spread over three years, in aid of the investigations has been made by the National Federation of Iron and Steel Manufacturers.

Nitrogen Case-Hardening of Steel by the Homo Method.

(*Continued from page* 32.)

heating coils through the work chamber, as indicated by arrows in the diagram. In this furnace the fan reverses its direction every minute, and thus the direction from which the work receives the gas is continually changing. This is incorporated in the design with a view to maintaining uniform conditions, so that the work will receive uniform treatment.

In starting the furnace, the electrical connections are closed so as to cause maximum heating. When the temperature nears the control figure, the controller automatically changes the connection in order to lower the rate of heating and prevent the required temperature being exceeded. The temperature advances evenly to the control point, and is held there for any length of time.

This type of furnace is well beyond the experimental stage, as many are now being successfully used commercially, and these have shown that the case-hardening produced is uniform, the work is clean and not oxidised, and there is no difficulty in loading or unloading the work container. The furnace facilitates deliberate variations in the search for ideal procedure to suit the work, while maintaining accurate control, in such a manner that results can be duplicated at any time.

Season Cracking of Brass.

A particularly animated consideration was given to the problem of season cracking when corrosion under specialised conditions was discussed by the Institute of Metals division at the annual convention of the American Institute of Mining and Metallurgical Engineers recently. "It is generally understood," says the *Iron Age*, "that fracture without ductility is produced in high brasses, stressed internally or externally beyond a certain figure and slightly corroded." Very small traces of ammonia gas seems to be a very active agent.

An attempt to fix quantitatively some of the factors affecting this phenomenon was made by Alan Morris, by exposing a round test piece, while under tension, to concentrated ammonia fumes. Fracture occurred rapidly on high loads; longer times were required with decreasing loads. Limiting values for a high grade 65—35 brass were as follows:—Annealed to 0·015 mm. grain size—10,000 lb. per sq. in. Annealed to 0·065 mm. grain size—5,000 lb. per sq. in.

Naval brass (Cu 60, Sn 0·75, Pb 0·10) gave the following limiting values below which corrosion fractures did not occur after 700 hr.:—Quenched from 500° C.—15,500 lb. per sq. in. Air cooled from 500° C.—3,000 lb. per sq. in.

Many doubted the conclusion that lead and tin in an alpha brass tended to accentuate corrosion cracking. One speaker suggested that lead is more or less innocuous as to season cracking, but promotes "fire cracking." The action of the insoluble lead particles in a piece of hot brass was likened to that of mercury in the convential test of season cracking, both being foreign substances with the power of selective attack.

As a practical matter brasses having 75% or more copper seldom season crack. This was borne out by W. B. Price, who stated that when assembling pipe fittings of high brass a torque of 20 ft.-lb. should not be exceeded. His tests showed that fittings made of brass containing 89% copper, 2% lead, and 1% nickel, would show no fractures in the mercury test when assembled with torque up to 60 ft.-lb.

Instances of season cracking in pure copper were referred to by W. H. Bassett. Any strained metal is less strong than in the unstrained condition, and the tendency to corrode more rapidly is there, even though in most commercial applications the magnitude of the actual damage is too slight for harmful results. In practice, it appears that those alloys which exhibit the phenomenon of dezincification on corrosion are also the ones which are liable to season crack.

Business Notes and News

Developments at South Cave Sand Quarries.

The Lord Mayor of Hull (Councillor Richard Richardson) performed a most interesting ceremony recently when he opened the new plant erected at the South Cave Moulding Sand Quarries, in which Messrs. General Refractories, Ltd., of Sheffield, and Messrs. The Yorkshire Amalgamated Products, Ltd., of Doncaster, are jointly interested.

One of the most modern plants in the country for the milling, mixing, and disintegrating of sand, has been installed, and the sand produced will prove of service to the foundries of Hull in particular, and of Yorkshire and the neighbouring counties generally. There are two excellent deposits of sand —one a strong bonded loam and the other a silica sand— which can be mixed to any consistency required, and from which many grades and mixtures of varying strength can be prepared to suit any foundry.

The plant was set in operation and sand, as quarried, was milled and disintegrated and then loaded into trucks, the whole operation being automatic after ths placing of the sand itself in the mill. Several grades were produced for the benefit of the visitors and a big feature is that the sand can be guaranteed to be regular and reliable without fear of those disturbing variations of quality which are so great a source of trouble to the foundryman. After the sand has been carefully selected and mixed, it is well milled, and conveyed in buckets on a mechanical elevator to a shoot, from whence it is deposited direct into the truck. The sand, which belongs to the Upper Jurassic beds, has a face 40 ft. in depth and covers 30 acres.

There is no doubt that this new enterprise will be of inestimable benefit to founders. It shows that the refractories industry is fully alive to and anxious to help with the problems of the foundry, and the works at South Cave can be taken as an example of how genuinely first-class moulding sand can be produced.

Possible Effect of Washington Hours Convention on Crucible Steel Trade.

The members of the Crucible Steel Makers' Association, who held their annual meeting at Sheffield recently, had under consideration the proposal of the Government to ratify the Washington (Hours) Convention. This is a matter of the greatest importance to trade, as, it is stated, a literal ratification of the Convention would shut down more than 50% of the melting holes. The Government's Hours of Industrial Employment Bill, recently issued, was accordingly very carefully considered, and future action decided upon.

Staffordshire Mines Close Down.

It is regrettable that five pits belonging to the Midland Coal, Coke and Iron Company, known as the Apedale Collieries and the Podmore Hall Collieries, have closed down. The blast furnaces, coking and by-producr plants are also involved in this unfortunate loss to Staffordshire. The difficulties under which they were operating has been known for some time, but it was hoped to overcome them rather than to take the drastic steps of closing down the undertaking.

The Durham Bursary of the Junior Institution of Engineers.

The Junior Institution of Engineers announces that the above Bursary, founded in 1908, of the annual cash value of £25, competition for which has hitherto been confined to members of the Institution, has recently been thrown open for competition to all young men between the ages of 20 and 22 years, of British parentage, who are in course of training for the engineering or an allied profession by employment in a technical office or works, or by attendance at a recognised institute, college, or university, or in some other manner approved by the Council of the Institution. Competition for the Bursary is by the submission of a thesis on some engineering, technical, or scientific subject selected by the candidate. The final date in any year for the receipt of theses is August 1.

Detailed conditions and entry forms may be had on application to the Secretary of the Institution at 39, Victoria Street, S.W. 1.

British Compressed-Air Society:

The British Compressed-air Society has recently been formed in order to promote and develop the interests of British air compressor, pneumatic tool, and pneumatic appliance manufacturers. The users of compressed air are extending rapidly, and it is proposed to assist its further extension by educational work. It is the intention of the Society to produce regularly a Bulletin with a view to broadcasting information likely to facilitate the use of compressed air and to be of mutual assistance to its members. We understand that most of the leading manufacturers in the industry are members of this Society, and a united effort is being made to give it a sound and useful basis. The Hon. Secretary is A. Vincent Clarke, A.M.Inst.C.E., I.M.Mech.E., of the Hamworthy Engineering Co., Ltd., Poole.

A.S.T.M. Change Wrought Iron Definition.

At the spring meeting of certain committees of the American Society of Testing Materials a new definition for wrought iron was recommended and was unanimously approved. The new definition states "Wrought iron is a ferrous material aggregated from a solidifying mass of particles of high refined metallic iron with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag."

The committee also voted to delete the definition of puddling from the list of definitions since no other process of manufacture is defined by the American Society of Testing Materials. It is intended to revise the process clauses of all specifications covering wrought iron products in order to eliminate reference to the process of manufacture.

Two New Directors to Board of Andrews Toledo, Ltd.

Andrews Toledo, Ltd., announce the election of two new, directors, Lt.-Col. H. H. Johnson, D.S.O., M.I.M.E., M.I.M.M. and Mr. A. W. P. Macwhinnie, F.C.I.S., A.S.A.A., to the Board. Lt.-Col. Johnson, who is the general manager of the Company, is a past president of the South African Institute of Engineers, and was formerly manager of Village Deep, Ltd. (Johannesburg), and later managing director of Tilmanstone Collieries, Ltd. Mr. Macwhinnie is general manager of Dawnay, Day and Co., Ltd., merchant bankers, and a director of Falkland Shipowners, Ltd., Anglo-Norse Co., Ltd., and Falkland Whaling Co., Ltd. He is a well-known costing expert.

Andrews Toledo, Ltd., was formed last year to take over the long-established Toledo Steel Works of J. H. Andrew and Co., Ltd., of Sheffield, as a first step in a policy for rationalising the very highly specialised branch of the steel industry in which this firm was engaged. Provision is now being made, it is stated, for increasing output and reducing production costs in every branch of the company's activities. The addition of the new directors to the board will, it is considered, considerably strengthen the company's position.

New Aluminium Alloy Developed.

A recent aluminium alloy development was referred to by Dr. Zay Jeffries, in a paper he presented at the regional meeting of the American Society of Testing Materials, which may have far-reaching effects in reducing troubles resulting from the present close-fitting aluminium pistons. This development is the result of research work carried out by the Aluminium Co. of America. They have produced an alloy, No. 132, having a coefficient of expansion of 0·0000105 per degree Fahr. between 70° and 212° Fahr., or 20% less than that of pure aluminium, and 15% less than the aluminium alloys at present being used for pistons, containing about 10% of copper. The clearance used is not merely a matter of coefficient of expansion of the piston alloy, but depends also on the coefficient of expansion of the cylinder and the heat-conductivity of the piston. No. 132 alloy can be fitted with 20% less clearance than the ordinary aluminium in a cast-iron cylinder. This new alloy has about the same expansion as the austenitic or non-magnetic irons and steels. One of these irons, which contains about 20% Monel metal, with some chromium and manganese, can be cast like cast iron, and has a coefficient of expansion of about 0·0000095 per degree Fahr., between 70° and 212° Fahr. The austenitic stainless steels of the Nirosta type, and Hadfields manganese steel also have the proper thermal expansion for use with No. 132 alloy.

Some Contracts.

Dorman, Long and Co., Ltd., Middlesbrough, have been awarded a contract by the Ministry of Communications, Egypt, for the construction of a swing bridge over the Marmondieh Canal at a cost of £E13,551.

The Crown Agents for the Colonies have put an order for eight tank locomotives, for the Gold Coast Railways, with the Hunslet Engine Co., Ltd., Leeds. The engines required are of the eight-wheeled coupled type, with cylinders 18 in. diameter, 23 in. stroke, and boiler pressure 180 lb. per sq. in.

Premix Gas Plants Co., Westminster, London, S.W. 1, have received orders from the South Wales Cannister Co., Swansea, for a purifying and compressing plant for producer gas with a capacity of 12,000 cub. ft. an hour, and from the Mond Nickel Co., Swansea, for converting several of their decomposers to special radiant system for heating.

The British Broadcasting Corporation has entrusted to Radio Communication Co., London, W.C. 2, a contract for the supply and erection of three 500-ft. lattice-steel masts at the north regional broadcasting transmitter, Slaithwaite, near Huddersfield, Yorkshire.

The Great Western Railway Co. have placed an order with the Siemens and General Electric Railway Signal Co., Ltd., of Central House, Kingsway, W.C. 2, for the supply of 1000 direct-current track relays having four front and two back contacts. The relays will be manufactured at the works of the Siemens and General Electric Railway Signal Co. at North Wembley, and will be entirely of British material. This is claimed to be the largest single order ever placed in this country for this particular type of signalling apparatus.

The English Electric Co., Ltd., have received an order from the Ashton-under-Lyne Corporation Tramways Committee for six single-deck petrol omnibus bodies, each to seat 31 passengers, and arranged with a rear entrance. The bodies will be mounted on Leyland "Lion" chassis.

A large fleet of giant air liners is now under construction to the order of Imperial Airways for use on new Empire air routes. The fleet will consist of land machines and flying-boats, and will have accommodation for over 500 passengers. Eight 40-seater biplanes, each driven by four engines totalling 2000 h.p., are being built for use on the land section of the routes to India, South Africa, and Australia. For the overseas portion of these routes a number of 40-seater all-metal flying-boats are being constructed. Flying-boats also will be used for the Nile and Great Lakes portions of the Cairo-Capetown air route, while the southern section of this route will be operated by triple-screw air liners.

The James Dredging, Towage, and Transport Co., Ltd., Southampton, it is understood, have received three contracts to the total value of about £1,000,000. The biggest of these contracts is in connection with the River Bann drainage scheme, the object of which is to obviate flooding, which periodically takes place from Lough Neagh. This contract is for £650,000. The other contracts are for harbour improvement work at Douglas, Isle of Man, and Folkestone. The effect of these contracts will be felt in the shipbuilding industry, for orders are being placed by the company for two new dredgers of special dimensions for the Irish work, together with a new tug and auxiliary plant.

The Great Western Railway Co. have placed orders for 100 engines, of the 0—6—0 class, with the following firms:—Messrs. Armstrong Whitworth, Ltd, 25; Messrs. W. E. Bagnall, Ltd., 25; Messrs. Beyer Peacock and Co., Ltd., 25; and the North British Locomotive Co., Ltd., 25. The value of the order exceeds £250,000.

Messrs. Nasmyth, Wilson and Co., Patricroft, Manchester, have received orders from the Barsi Light Railway, India, for two 4—6—4-type locomotives, and from the Crown Agents for the Colonies for three 4—8—0-type locomotives and tenders for service on the Tanganyika Railway.

The Staveley Coal and Iron Co. have secured the manufacturing rights for the British Isles under an American patent for the production of sand-spun iron pipes. It is understood that a new foundry will be necessary, and work has now begun on the clearing of a site close to the company's general offices at Barrow Hill. Production is expected to commence next year.

The whole of the metal windows for the new Ford factory to be erected at Stockholm are to be supplied by Messrs. Williams and Williams, of Chester. The building will be one of the largest in Sweden. This contract has been secured in the face of very severe competition.

Messrs. Charles Walmsley and Co., of Bury, have secured a large order for paper machinery from Messrs. Hanmaren and Co., of Helsingfors. This is the second time within a year that the Finnish paper industry has purchased plant in England.

The Power Gas Corporation have secured a contract from the Soviet authorities for a semi-water-gas plant with automatic control gear. The works are for the Urals district, and will be erected there by the Stockton firm. The contract is believed to be worth about £100,000.

The London and North Eastern Railway have placed an order for 20 locomotives of the K3 2—6—0 type with Messrs. Armstrong Whitworth, Ltd., Newcastle-on-Tyne.

The Metropolitan Cammell Carriage, Wagon, and Finance Co., Birmingham, have received orders from the Crown Agents for the Colonies for 200 four-wheeled all-steel covered goods wagons, two under-frames and bogies for saloon coaches, and two sets of electrical equipment for saloon coaches.

The Anglo-Soviet Trading Delegation, Bush House, London, W.C. 2, have placed the following orders during the past week:—Jute and manilla hemp with various British firms in London to the value of £105,000; turbo-alternator sets for service in Kulsk Power Station with the General Electric Co., Magnet House, Kingsway, London, W.C. 2, to the value of £10,210; 17 compressors with Broom and Wade, Ltd., High Wycombe, Bucks., £11,208; two turbo-compressors with Reavell and Co., Ipswich, £7,500; industrial diamonds to the value of £15,708 with L. M. Van Moppes and Sons, London, E.C. 1. Further contracts have been placed with Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester, for electrical equipment to the value of £120,000; with Ruston and Hornsby, Ltd., Lincoln, for crude-oil engines for the Russian oil industry to the value of £50,000; with Marshall and Sons, Gainsborough, for steam engines for the Russian timber industry to the value of £65,000; with Greenwood and Batley, Ltd., Leeds, for boring lathes to the value of £17,000; with James Mackie and Sons, Belfast, for textile machinery to the value of £13,000.

The L.M.S. Railway Co. have ordered from Messrs. Greenwood and Batley, Ltd., Albion Works, Leeds, eight industrial electric trucks (flat platform type, fitted with D.P. batteries) for dealing with luggage at the new landing-stage at Tilbury.

New Plymouth Borough Council, New Zealand, have awarded a contract for 11,000 volt transformers, step-up transformers for power-stations, and step-down transformers for sub-station, with the Metropolitan-Vickers Co., Manchester. This company have also been awarded a considerable part of the contract for transformers for power, lighting, and signalling for the Madras electrification scheme.

Messrs. Robt. Boby, Ltd., St. Andrew's Works, Bury, Suffolk, have been awarded a contract for the supply and erection of a coal-handling plant for the Ipswich Electricity Supply Co.

The Buenos Aires Pacific Railway are placing an order with Robert Stephenson and Co., Ltd., Darlington, for 15 locomotives, when specifications have been settled.

The Associated Equipment Co., Ltd., Southall, Middlesex, have booked orders for 28 motor-omnibuses and goods vehicles for, among others, Chester Corporation (four), Amersham and District Motor Services (two), Ayr and District Motor Services, and the Highland Transport Co.

Iron and Steel Report.

No real improvement in the condition of the iron and steel trades has occurred during the past month. Users of Midland common irons who were holding up buying in the confident expectation that the end-of-April meeting of the Producers' Association would result in lower prices for foundry grades were disappointed, makers asserting that current costs of production did not warrant any reduction in selling prices. Consumers had long been following this waiting policy, with the consequence that few of them had much tonnage against which to draw for deliveries. Since the meeting of producers several weeks ago there has to some extent been a renewal of contract buying, but it has not amounted to much, and in very few instances indeed have recent commitments gone beyond the end of the current month.

There is a twofold reason for this. In the first place, users are still not without hope that sooner or later a downward movement of foundry-iron values will set in, and the probability is that buying operations will continue to be restricted to near-delivery positions until something tangible develops. Secondly, there is no disputing the fact that foundry trade conditions in almost every district are far from satisfactory. This is particularly the experience in the heavy branches, some degree of seasonal improvement having recently been recorded in respect of one or two of the lighter sections. Few firms, however, are in a position to see any distance ahead, and the consequence is that, quite apart from the influence of prices on forward contract buying, there is no justification from the consumer's point of view in covering themselves much in advance of current needs.

Whilst, as has been indicated, the general run of foundry-iron users have been awarded no concessions in prices by Midland producers, the latter have considered it expedient to reduce rates slightly in certain areas where North-east Coast brands have latterly been offering on a keenly competitive basis. Certain points in Yorkshire, and also in the London district, for example, are now in a position to secure Derbyshire and Staffordshire makes at slightly below the prices current a month ago. Small concessions have also been made in the case of forge iron, but only where this material is employed solely for forge purposes. Lancashire users are now obtaining it at 5s. a ton below No. 3 foundry, instead of 4s., current value for delivery in the Manchester prices zone now being 72s.

The movement in finished iron is of fair extent so far as the higher-grade products are concerned, but in the lower-quality materials operations both in the Midlands and in Lancashire are on a very restricted scale, Continental stuff being freely offered at appreciably lower prices than makers on this side can meet.

Complaints from the heavy steel trade as to the unsatisfactory conditions have been almost general throughout the past month. The movement into shipyard consumption has been very moderate, and interest has been restricted also so far as constructional engineering in most districts is concerned. In the latter branch the more usual experience is that work in hand is being executed quicker than new jobs of any weight are coming into sight, with the result that both new bookings by the rolling-mills and delivery specifications against old contracts have been relatively small. A not unsatisfactory business has been done with locomotive builders, some good additional contracts having been announced during the past few weeks. Textile machinists and general engineers are poor steel buyers just now, though fair quantities are being taken by heavy electrical engineers and speciality firms in one or two lines. Boilermakers are very poorly engaged, and what little steel buying is going on in this section is for the most part in connection with repair jobs. Rerollers are finding very slow markets for their products, and this, in turn, is reacting on sales of foreign semi-finished materials.

Ferro-Alloy Report.

THE situation is not changed and business is in a very depressed state. There is no activity of any moment, buyers continuing to cover their requirements as they are needed, and the prospects are not very optimistic. There is too much uncertainty regarding the future for buyers to commit themselves for forward delivery, and the political situation appears to have some bearing. The disturbances overseas appear to affect every branch of industry, and may possibly account for the falling-off in business in alloys. The quantities under requisition are small, and very few demands under contract are being made. The Australian situation as well as the position in India does not tend to improve matters, and, until the situation becomes clearer, it is hardly likely there will be a revival in the ferro-alloy market. Prices at the present are at a low ebb and favour the buyer.

The interest in ferro chromes continues to be concerned with low-carbon varieties, other grades being neglected and calls only made for very small quantities. The prices show no change. In connection with ferro silicon all grades are changing hands, but only in very small quantities, and contracts proceed very slowly. There is no change in the position regarding tungsten, prices remaining the same, and a hand-to-mouth policy continues to govern orders. The demand for ferro vanadium is very low and is apparently getting worse, but the price remains unchanged. The business in ferro molybdenum is very dull and stagnant; there is no expansion in cobalt; the market in this alloy continues to be fairly regular at old-price levels. Ferro titanium is very poorly supported, without alteration in price. Some parcels of silico manganese have changed hands, but the tonnage is still far below normal. Other alloys have little of interest to note.

The Copper Cut.

THE announcement that the American copper producers had at last cut the price is an event of far-reaching importance. It has been increasingly evident for some time past that the policy of the Copper Trust had been operating contrary to ordinary economic principles, and it has been difficult to appreciate the reason why the leaders of the copper industry should adopt a policy opposed to the whole course of trade. The tendency has undoubtedly been to drive consumers to adopt substitutes and expedients not in keeping with their regular methods of business. No doubt the heavy cut in price will result in considerable buying, as in all probability the stocks of consumers are low; but there also is no doubt that a lack of confidence prevails, and this can only be due to the unenviable record of the two large copper organisations in handling the market. What is needed is the establishment of a healthier market. Consumers require an assurance that there will be an attempt to adhere strictly to the original intentions of the Trust, that of effecting stabilisation in the industry. Experience has shown the futility of attempting to produce and distribute a world's basic commodity without the governing influence of an open market. This break in copper represents one more instance in which efforts had been made to control artificially a market of this kind.

Early in the year an official announcement declared that if the price was lowered the structure created to control them would definitely fall to pieces, and that in fighting to maintain the special price the Trust was endeavouring to establish the stabilisation of prices, based on scientific calculations if the world's supplies were to be maintained in years to come. The chairman of the Rio Tinto Co., who is fully aware of the new sources of the metal being developed in South Africa and Canada, stated that if work of developing new supplies does not proceed regularly there will be a copper famine by 1935-40 at the latest.

Whatever may be the objective of the producers, an effort should be made to establish better relations among all interests in the trade and so create more confidence.

MARKET PRICES

ALUMINIUM.

99% Purity	£95	0	0
Castings, 2.L5 Alloy	lb.	1/3–1/8	
„ 2.L8 „	„	1/4–1/9	
„ Silicon „	„	—	

ANTIMONY.

English	£40	0	0
Chinese	29	0	0
Crude	20	0	0

BRASS.

Solid Drawn Tubes	lb.	11½d.
Brazed Tubes	lb.	13½d.
Rods Drawn	„	10½d.
Wire	„	9½d.
*Extruded Brass Bars	„	6d.

COPPER.

Standard Cash	£48	7	6
Electrolytic	56	0	0
Best Selected	56	10	0
Tough	56	0	0
Sheets	92	0	0
Wire Bars	61	7	6
Ingot Bars	61	7	6
Solid Drawn Tubes	lb.	13d.	
Brazed Tubes	„	13d.	

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	£0	3	1
‡Ferro Tungsten	„	0	2	10
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
2-4% Carbon, scale 11/- per unit	ton	30	12	6
4-6% Carbon, scale 7/- per unit	„	23	12	6
6-8% Carbon, scale 7/- per unit	„	22	12	6
8-10% Carbon, scale 7/- per unit	„	22	7	6
Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 10/- per unit	„	33	15	0
Guar. max. 1% Carbon, scale 13/6 per unit	„	38	2	6
Guar. max. 0.7% Carbon, scale 15/- per)unit	„	40	12	6
‡Manganese Metal 96-98% Mn.	lb.	0	1	3
‡Metallic Chromium	„	0	2	7
Ferro-Vanadium 25-50%	„	0	12	9
Spiegel, 18-20%	ton	7	5	0
Ferro Silicon—				
Basis 10%, scale 3/- per unit	ton	5	17	6
‖20/30% basis 25%, scale 3/- per unit	„	7	0	0
‖45/50% basis 45%, scale 5/- per unit	„	10	17	6
‖70/80% basis 75%, scale 6/- per unit	„	17	10	0
‖90/95% basis 90%, scale 10/- per unit	„	25	6	0
Silico Manganese 65/75% Mn., basis 65% Mn.	„	14	0	0
Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	6
Ferro Phosphorus, 20-25%	ton	16	0	0

FUELS.

Foundry Coke—						
S. Wales Export	£1	10	0	to £1	17	0
Sheffield „	0	19	6	„ 1	0	0
Durham	1	6	0	to 1	9	0
Furnace Coke—						
Sheffield Export	£0	19	6	to £1	0	0
S. Wales „	1	5	0	to 1	7	6
Blast-Furnace Coke, at ovens		0	17	0		

GUN METAL.

Commercial Ingots	£71	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	1	0
*Cored Bars	„	0	1	2

LEAD.

Soft Foreign	£17	12	6
English	19	0	0

MANUFACTURED IRON.

Scotland—			
Crown Bars	£10	5	0
N.E. Coast—			
Rivets	11	10	0
Best Bars	11	5	0
Common Bars	10	15	0
Lancashire—			
Crown Bars	10	15	0
Hoops	13	0	0
Midlands—			
Crown Bars	10	7	6
Marked Bars	12	10	0
Unmarked Bars		—	
Nut and Bolt Bars	9	2	6
Gas Strip	11	2	6
S. Yorks.—			
Best Bars	11	10	0
Hoops	12	0	0

PHOSPHOR BRONZE.

*Bars, Tank brand, 1 in. dia. and upwards	lb.	1/–
*Cored Bars	„	1/2
†Strip	„	1/2
†Sheet to 10 W.G.	„	1/3
†Wire	„	1/3½
†Rods	„	1/2½
†Tubes	„	1/6½
†Castings	„	1/2

†10% Phos. Cop. £25 above B.S.
†15% Phos. Cop. £30 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—			
Hematite M/Nos.	£4	1	0
Foundry No. 1	4	0	6
„ No. 3	3	18	0
N.E. Coast—			
Hematite No. 1	3	14	6
Foundry No. 1	3	10	0
„ No. 3	3	7	6
„ No. 4	3	6	6
Cleveland—			
Foundry No. 3	3	7	6
„ No. 4	3	6	6
Silicon Iron	3	15	0
Forge No. 4	3	6	0
N.W. Coast—			
Hematite	4	10	6
Midlands—			
N. Staffs Forge No. 4	3	15	6
„ Foundry No. 3	3	19	6
Northants—			
Forge No. 4	3	11	0
Foundry No. 3	3	15	0
Derbyshire Forge	3	14	6
„ Foundry No. 3	3	18	6
West Coast Hematite	4	10	0
East „ „	4	9	0

SWEDISH CHARCOAL IRON AND STEEL.

Pig Iron	£6	0	0	to	£7	10	0	
Bars, hammered, basis	£17	10	0	„	£18	10	0	
Blooms	£10	0	0	„	£12	0	0	
Keg steel	£32	0	0	„	£33	0	0	
Faggot steel	£20	0	0	„	£24	0	0	

All per English ton, f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£46	0	0
„ Brazier	43	0	0
„ Wire		—	
Brass	34	0	0
Gun Metal	43	0	0
Zinc	9	0	0
Aluminium Cuttings	63	0	0
Lead	15	0	0
Heavy Steel—			
S. Wales	3	2	6
Scotland	3	0	6
Cleveland	2	17	6
Cast Iron—			
Lancashire	3	2	6
S. Wales	2	18	0
Cleveland	3	2	6
Steel Turnings—			
Cleveland	2	11	0
Lancashire	1	15	0
Cast Iron Borings—			
Cleveland	2	8	0
Scotland	2	10	0

SPELTER.

G.O.B. Official		—	
Hard	£13	10	0
English	16	7	6
India	14	10	0
Re-melted	15	5	0

STEEL.

Ship Plates (Scotland)	£8	15	0
„ „ (N.E. Coast)	8	15	0
Boiler Plates (Land), Scotland	10	0	0
„ „ (Marine) „	10	10	0
„ „ (Land), N.E. Coast	10	0	0
„ „ (Marine) „ „	10	10	0
Sheets 20 W.G.	11	15	0
Angles (N.E. Coast)	8	7	6
„ (Midlands)	8	7	6
Joists	8	10	0
Heavy Rails	8	10	0
Fish-Plates	12	0	0
Light Rails	8	17	6
Sheffield—			
Siemens Acid Billets	9	10	0
Hard Basic	9	12	6
Medium Basic	8	2	6
Soft Basic	6	10	0
Hoops	9	15	0
Manchester—			
Hoops	10	0	0
Bridge and Tank Plates	8	17	6
Angles	8	7	6
Tool Steel, High Speed—			
Finished Bars 18% Tungsten	lb.	3/–	
Round and Squares, ½ in. to ½ in.	„	3d.	
Under ½in. to $\frac{3}{16}$ in.	„	1/–	
Round and Squares 3 in.	„	4d.	
Flats under 1 in. × ¾ in.	„	3d.	
„ „ ½ in. × ½ in.	„	3d.	

TIN.

Standard Cash	£145	5	0
English	146	5	0
Australian	143	7	6
Eastern	143	0	0
Tin Plates I.C. 20 × 14	box	18/6	
Block Tin Cash	£142	7	6

ZINC.

English Sheets	£27	10	0
Rods	30	0	0
Battery Plates	25	0	0

* McKechnie Brothers, Ltd., quoted May 9. † C. Clifford & Son, Ltd., quoted May 12. ‡Murex Limited, quoted May 12.

Pearson & Knowles' Current Basis Prices:—Wrought Iron Bars, £10 15s. 0d.; Mild Steel Bars, £8 0s. 0d. to £8 7s. 6d.; Wrought Iron Hoops, £12; Best Special Steel Baling Hoops, £9 15s. 0d.; Soft Steel Hoops (Coopers' and Ordinary Qualities), £9 to £9 5s. 0d.; C.R. & C.A. Steel Hoops, £12 10s. 0d. to £13 10s. 0d.; "Iris" Bars, £9 15s. 0d. All Nett Cash.

‖R. Hostombe, quoted May 13. Delivery c.i.f., suitable U.K. ports.